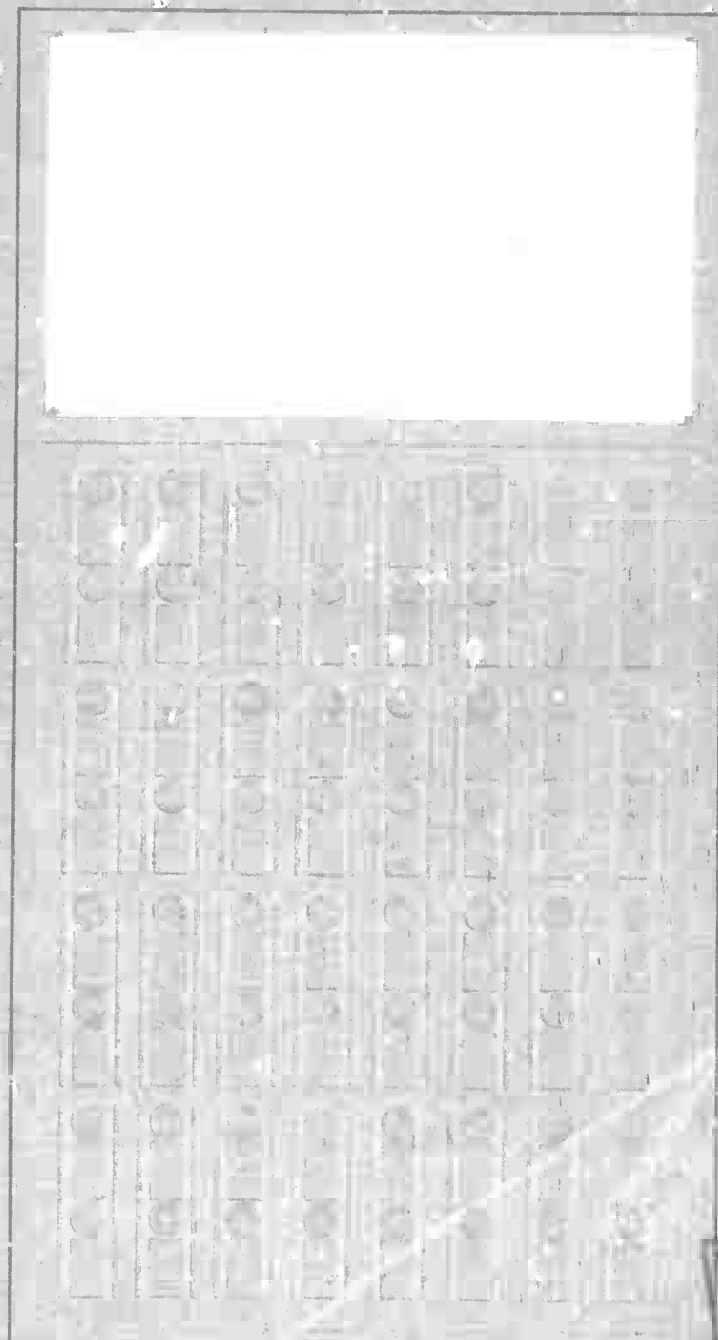
AFOSR - TR - 72 - 1959

AD 750128

informatics inc



NATIONAL TECHNICAL
INFORMATION SERVICE

DDC
OCT 24 1972

Approved for public release;
distribution unlimited.

BEST
AVAILABLE COPY

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Informatics Inc. 6000 Executive Boulevard Rockville, Md. 20852	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

Recent Soviet Investigations in Geothermy - Report 1

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Scientific . . . . Interim

5. AUTHOR(S) (First name, middle initial, last name)

Eleanor M. Rowell, Stuart G. Hibben

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May, 1972	90	

8a. CONTRACT OR GRANT NO F44620-72-C-0053 b. PROJECT NO A01622-3 c. 62701D d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFOSR - TR - 72 - 1959

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Tech. Other	Air Force Office of Scientific Research 1400 Wilson Boulevard (NPG) Arlington, Virginia 22209

13. ABSTRACT

This report presents the results obtained in an attempt to provide information on recent Soviet research on geothermy. Emphasis is on the identification and description of high-intensity heat flow areas in the USSR that have or might become potential sites for geothermal power or space heating developments. In general, the information provided consists of background data (geographical, geological and chemical) covering recently investigated areas. In some instances the data may be partially incomplete for some areas, i. e., may lack information on one or two of the above-mentioned three fields. Further search is required to close these gaps.

With only a few exceptions, no attempt has been made in this first report to supply references to Soviet publications dealing with the engineering problems associated with the building or maintenance of geothermal plants. It is anticipated that these problems will be treated in the next report of this series.

Details of illustrations in this document may be better studied on microfiche

DD FORM 1 NOV 65 1473

I A

UNCLASSIFIED

Security Classification

RECENT SOVIET INVESTIGATIONS IN GEOTHERMY

Report 1 - May 1972

Sponsored by

Advanced Research Projects Agency

ARPA Order No. 1622-3

ARPA Order No. 1622-3
Program Code No. 62701D2F10
Name of Contractor
Informatics Inc.
Effective Date of Contract:
January 3, 1972
Contract Expiration Date:
December 31, 1972
Amount of Contract: $250,000

Contract No. F44620-72-C-0053
Principal Investigator:
Stuart G. Hibben
Tel: (301) 779-2850 or
(301) 770-3000
Project Scientist:
Eleanor M. Rowell
Short Title of Work:
"Soviet Geothermy"

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the Air Force Office of Scientific Research under Contract No. F44620-72-C-0053. The publication of this report does not constitute approval by any government organization or Informatics, Inc., of the inferences, findings, and conclusions contained herein. It is published solely for the exchange and stimulation of ideas.

Prepared by

Informatics Inc.
6000 Executive Boulevard
Rockville, Maryland 20852

D D C
RECEIVED
OCT 24 1972
D

Approved for public release;
distribution unlimited.

IB

INTRODUCTION

This report presents the results obtained in an attempt to provide information on recent Soviet research on geothermy. Emphasis is on the identification and description of high-intensity heat flow areas in the USSR that have or might become potential sites for geothermal power or space heating developments. In general, the information provided consists of background data (geographical, geological and chemical) covering recently investigated areas. In some instances the data may be partially incomplete for some areas; i.e., may lack information on one or two of the above-mentioned three fields. Further search is required to close these gaps. Here, one might point out that a search for pertinent information on such areas as the Chukotka area (north of the Arctic Circle) might produce some interesting results.

With only a few exceptions, no attempt has been made in this first report to supply references to Soviet publications dealing with the engineering problems associated with the building or maintenance of geothermal plants. It is anticipated that these problems will be treated in the next report of this series.

TABLE OF CONTENTS

PART I. MAJOR REFERENCE WORKS ON THE GEOTHERMY OF THE USSR

HIGH-TEMPERATURE WATERS OF THE USSR

Bogoroditskiy, K. F. Vysokotermal'nyye vody SSSR (High-temperature waters of the USSR). Moskva, Izd-vo Nauka, 1968, 166 p.

The coverage below utilizes the large volume of illustrations in the book to provide pictorial and tabulated information on USSR geothermal areas, their water characteristics, etc., and to facilitate an "at-a-glance" assessment of the area development potential of the USSR as a whole.

Following the translated Table of Contents, the treatment of the book in this report is broken down into two major sections. Section A is an informative treatment of the most relevant information, which has been summarized in the illustrations and tables appearing in this section. Section B represents an indicative treatment of information which is either a detailed description of a specific small area (e.g., point-to-point geothermal sections - generalized on maps in Section A) or tabular data on chemical and mineralization aspects of geothermal sources. In both Sections, the original numeration of the maps and tables has been retained to facilitate reexploitation or relocation of the material in the event additional or more explicit information is required.

Table of Contents

References: Lists 54 items, 51 of Soviet Origin and 3 of Non-Soviet Origin

---

Section A.

Water-Temperature Classification Used by the Author in this Book (p. 11)

Cold Water	Temperature °C (°F)
Supercooled	<0(32)
Very Cold	0 - 10(32 - 50)
Cold	10 - 20(50 - 68)
Low-Temperature Waters	**Temperature °C(°F)**
Warm	20 - 37(68 - 100)
Hot	37 - 50(100 - 122)
High-Temperature Waters	**Temperature °C(°F)**
Very Hot	50 - 100(122 - 212)
Superheated	>100(212)

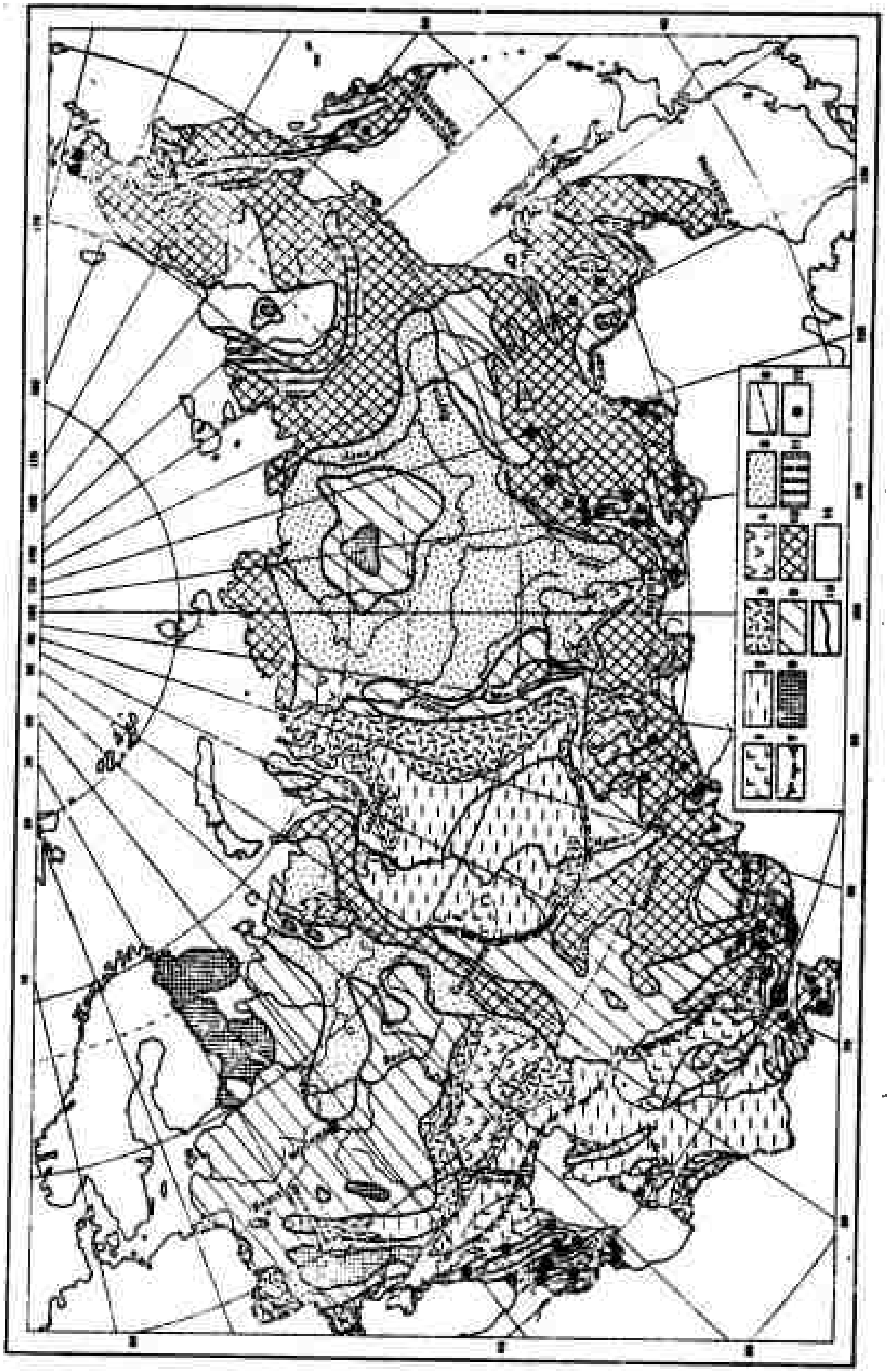


Fig. 1. Schematic Map Showing the Distribution and Depths of Occurrence of Hot Waters ($50^{o}C \pm 10$), i.e., $122^{o}F \pm 18^{o}$ (pp. 14-15).

Stratum and Stratum-Interstitial Waters. Areas (1 - 5) in which the predominant depths of hot waters are: 1 - less than 1000 m, 2 - 1000 - 1500 m, 3 - 1500 - 2000 m, 4 - 2000 - 2500 m, 5 - deeper than 2500 m; 6 - boundaries of areas, determined and postulated; 7 - boundaries of regions with possible artesian hot waters. Interstitial and Intertitial-Vein Waters. 8 - crystalline shields with possible occurrence of hot waters at great depths; 9 - basements of artesian basins with possible occurrence of hot waters in the deepest (still not verified by drilling) depressions and tectonic fault zones; 10 - fold-mountain areas in which hot waters occur in tectonic fault zones; 11 - upper structural stages of fold-mountain areas in which interstitial waters occur in small artesian basins; 12 - springs having temperatures of 40 - $60^{o}C$; 13 - boundaries of areas in which stratum, stratum-interstitial and interstitial and interstitial-vein waters occur; 14 - regions for which information is unavailable.

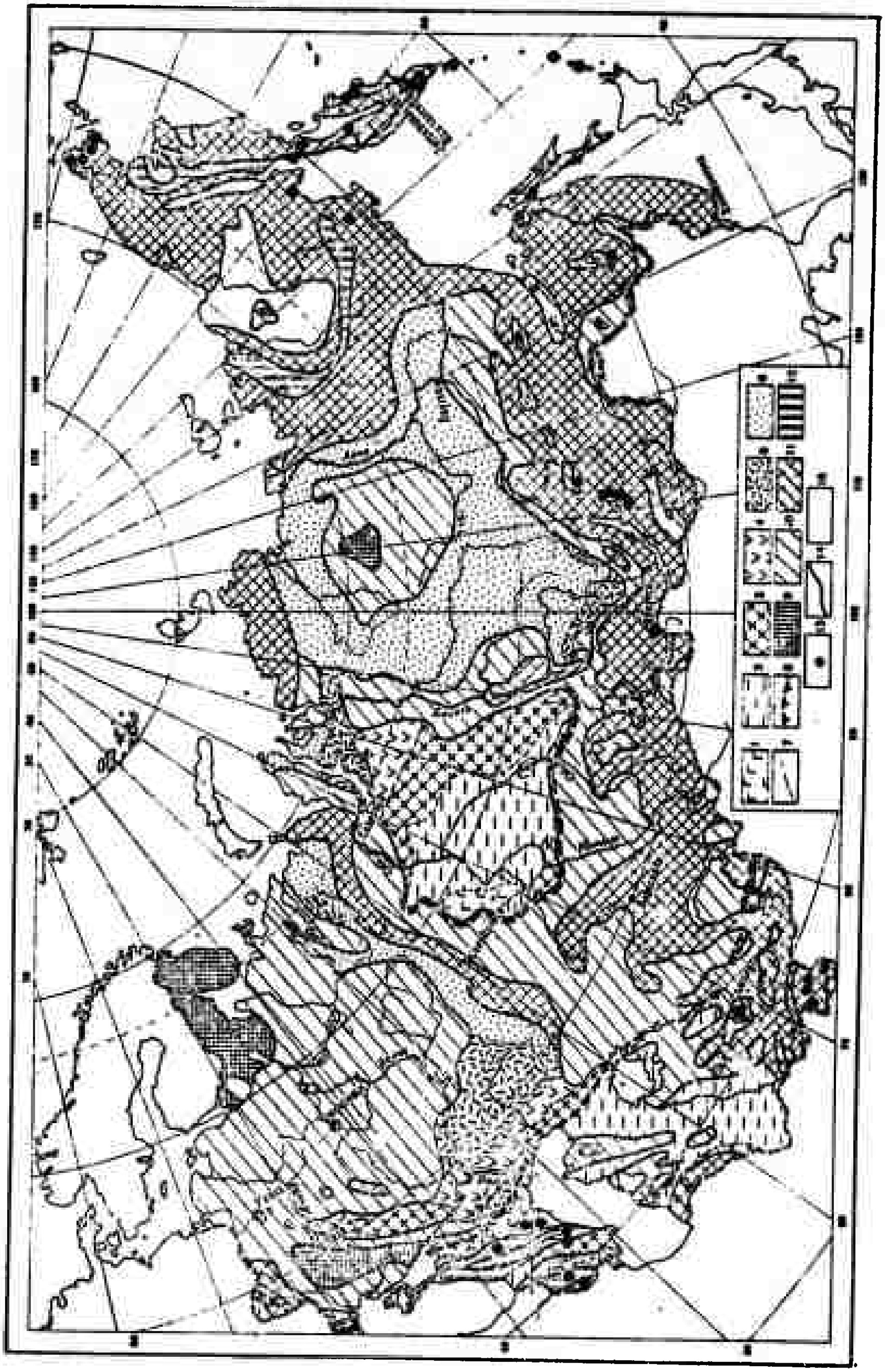


Fig. 2. Schematic Map Showing the Distribution and Depths of Occurrence of Very Hot Waters ($75^{\circ}C \pm 10$), i.e., $167^{\circ}F \pm 18^{\circ}$ (compiled by K. F. Bogoroditskiy and Ya. B. Smirnov) (p. 18).

Stratum and Stratum-Interstitial Waters. Areas (1 - 6) in which the predominant depths of very hot waters are: 1 - less than 1500 m, 2 - 1500 - 2000 m, 3 - 2000 - 2500 m, 4 - 2500 - 3000 m, 5 - 3000 - 3500 m, 6 - deeper than 3500 m; 7 - boundaries of areas, determined and postulated; 8 - boundaries of regions within which very hot artesian waters are possible. Interstitial and Interstitial-Vein Waters: 9 - crystalline shields with possible occurrence of very hot waters at great depths; 10 - basements of artesian basins with possible occurrence of very hot waters in the deepest (still not verified by drilling) depressions and tectonic fault zones; 11 - fold-mountain areas in which very hot waters occur in tectonic fault zones; 12 - upper structural stages of fold-mountain areas in which artesian waters occur in small artesian basins; 13 - hot springs with temperatures ranging from 60 to $90^{\circ}C$; 14 - boundaries of areas in which stratum, stratum-interstitial and interstitial and interstitial-vein waters occur; 15 - regions for which information is lacking.

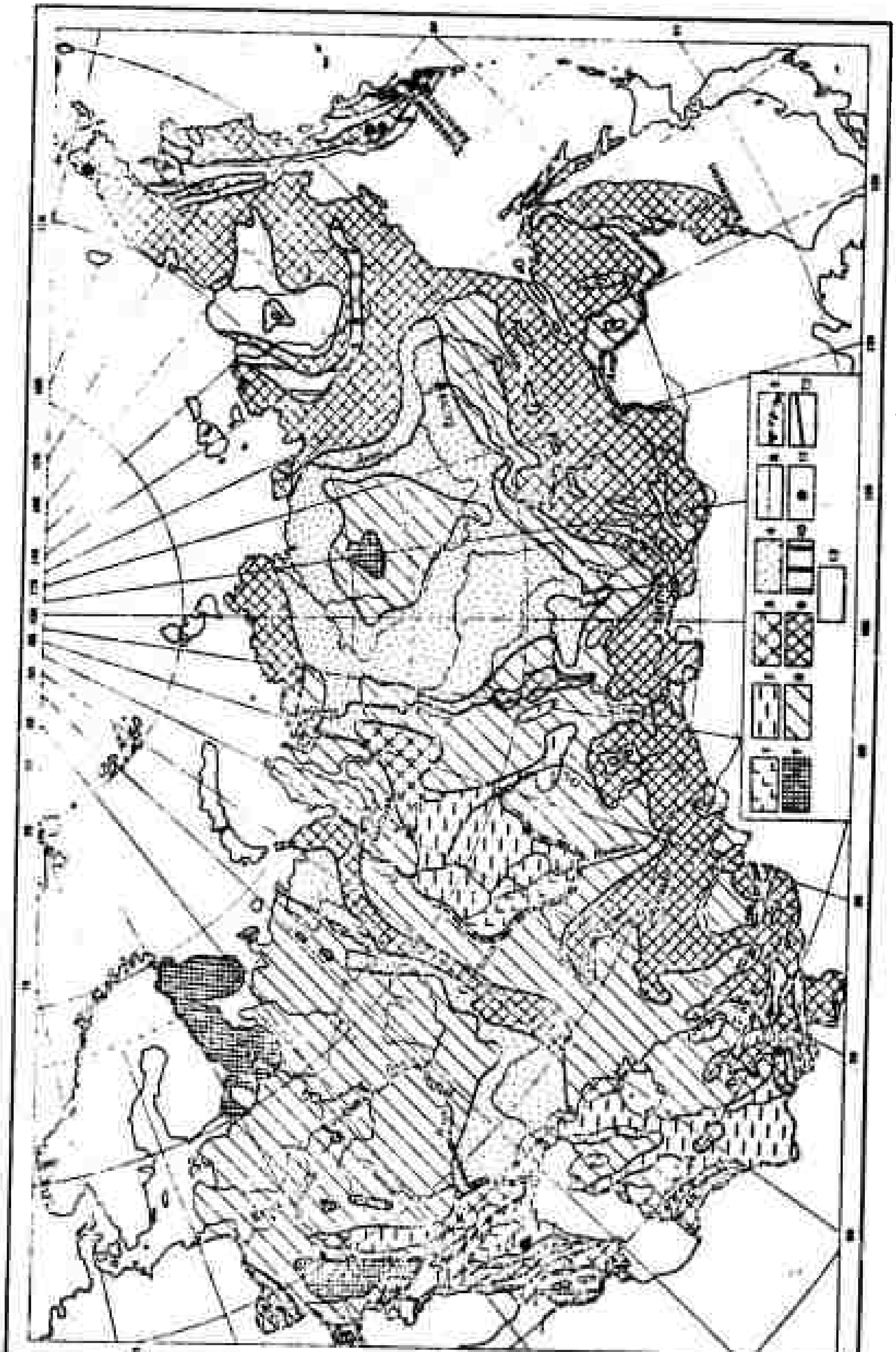


Fig. 3. Schematic Map Showing the Distribution and Depths of Occurrence of Superheated Waters ($100^{o}C \pm 10$), i.e., $212^{o}F \pm 18^{o}$ (compiled by K. F. B. Bogoroditskiy and Ya. B. Smirnov). (p. 22).

Stratum and Stratum-Interstitial Waters. Areas (1 - 4) in which the predominant depths of superheated waters are: 1 - less than 2000 m, 2 - 2000 - 3000 m, 3 - 3000 - 4000 m; 4 - more than 4000 m; 5 - boundaries of areas, determined and postulated; 6 - boundaries of regions in which superheated artesian waters are possible. Interstitial and Interstitial-Vein Waters. 7 - crystalline shields with possible occurrences of superheated waters at great depths; 8 - basements of artesian basins with possible occurrences of superheated waters at the greatest depths (still not verified by drilling) in depressions and tectonic fault zones; 9 - fold-mountain areas in which superheated waters occur in tectonic fault zones; 10 - upper structural stages of fold-mountain areas in which interstitial waters occur in small artesian basins; 11 - springs with water temperatures higher than $90^{o}C$; 12 - boundaries of areas in which stratum, stratum-interstitial and interstitial and interstitial-vein waters occur; 13 - regions for which information is lacking.

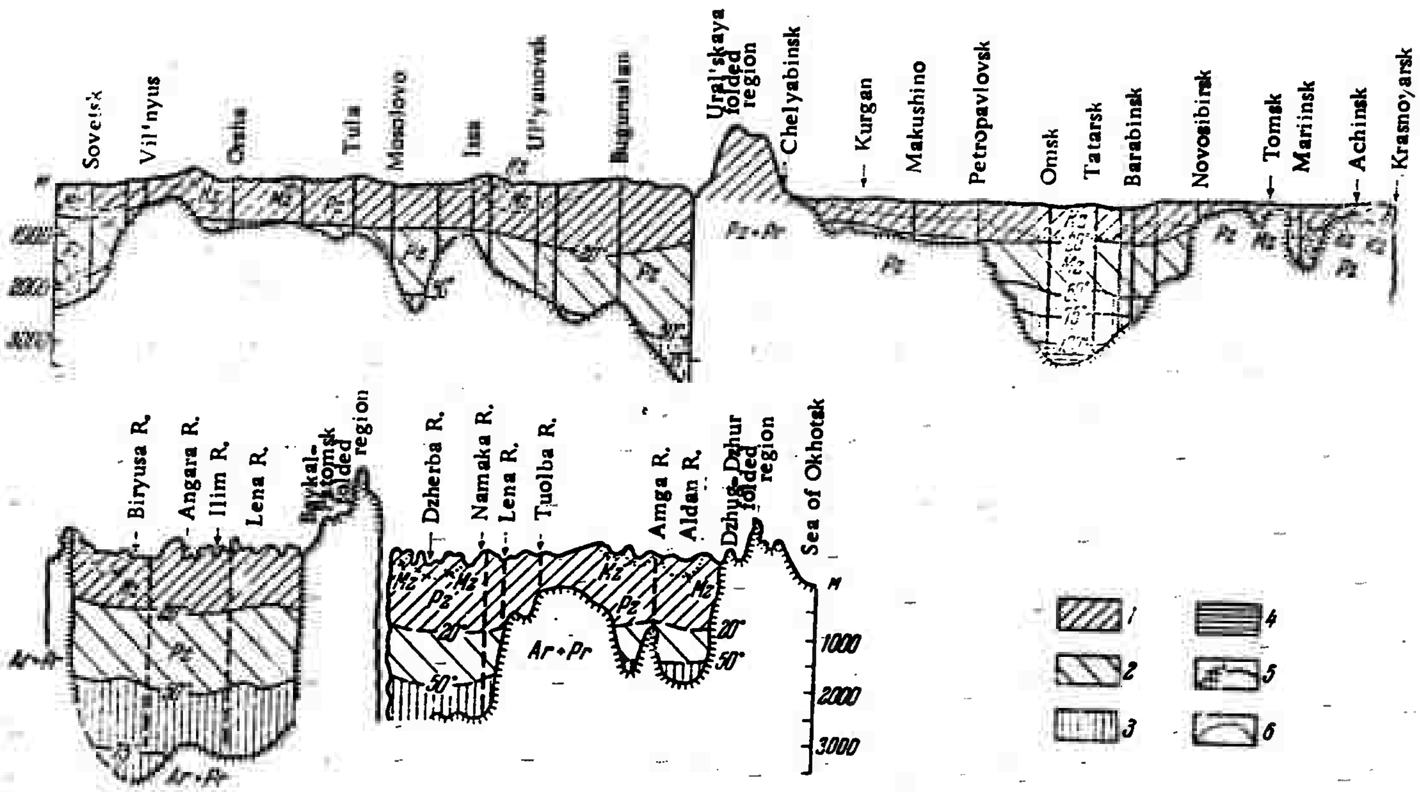


Fig. 10. Schematic Latitudinal Hydrothermal Section of the USSR (compiled by K. F. Bogoroditskiy and O. I. Grozdova on the geological base of the I. K. Zaytsev hydrochemical profile) (p. 49).

Zones (1 - 4) in which waters have temperatures of: 1 - lower than 20°C (cold water); 2 - from 20 to 50°C (warm and hot waters); 3 - from 50 to 100°C (very hot waters); 4 - above 100°C (superheated) waters; 5 - geoisotherms; 6 - stratigraphic contacts.

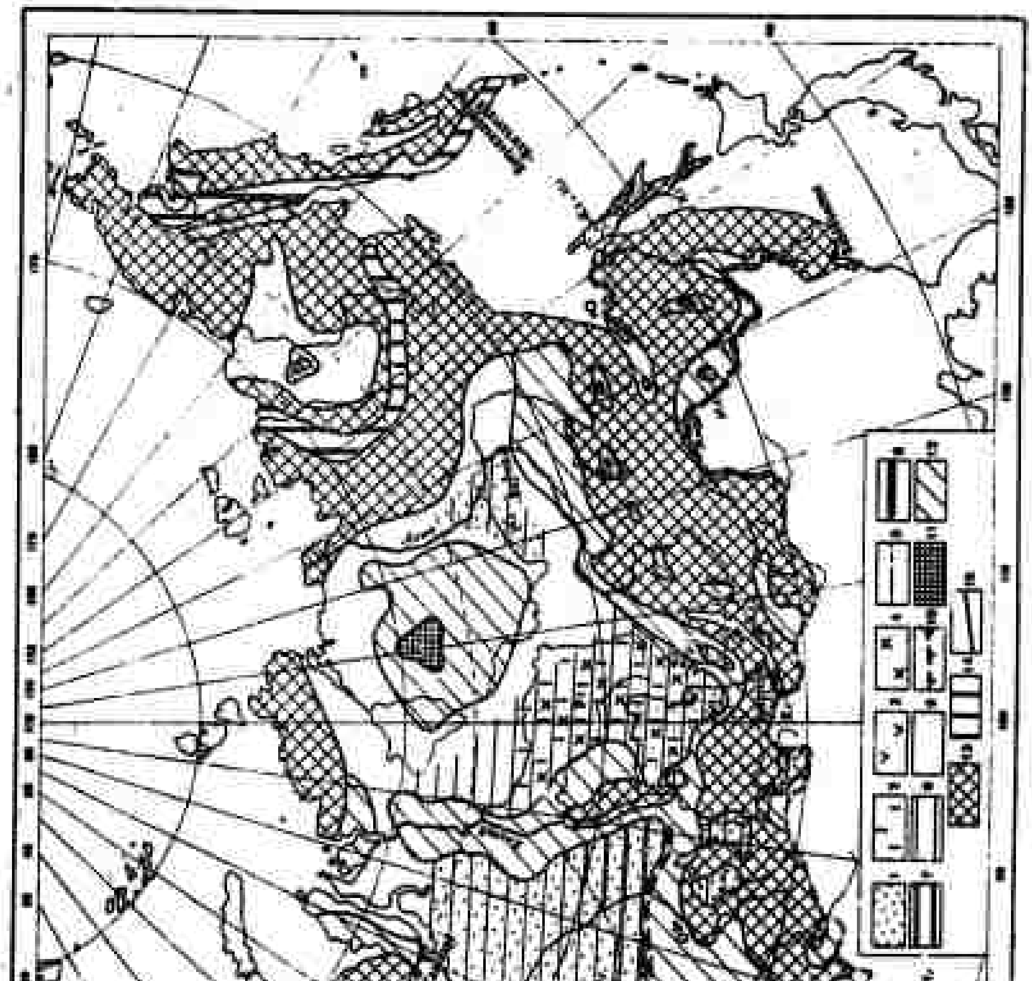


Fig. 12. Schematic Map Showing the Abundance of Water in Rocks Containing Very Hot Waters ($75^{o}C \pm 10$) in the USSR. (pp. 56-57).

Areas of Stratum and Stratum-Interstitial Waters. Water-bearing rocks (1 - 4): 1 - terrigenous; 2 - carbonaceous; 3 - tufaceous; 4 - saliferous; 5 - contacts between rocks of different age. Water abundance (6 - 9) of rocks (expected well discharge, m^3/day): 6 - exceedingly abundant water supply (mainly exceeding 1000); 7 - abundant supply (mainly from 250 to 1000); 8 - low-abundance (mainly up to 250); 9 - regions for which information is lacking; 10 - regions having possible artesian hot waters. Areas of Interstitial and Interstitial-Vein Waters: 11 - crystalline shields, occurrences of very hot water not recorded; 12 - basements of artesian basins, very hot waters encountered in individual wells in weathered-crust and tectonic fault zones; 13 - fold-mountain areas, occurrences of very hot waters noted in tectonically disrupted zones with discharges of wells and boreholes of the order of 1500, rarely 2500 m^3/day or more; 14 - upper structural stage of fold-mountain areas, distribution of small artesian basin interstitial waters, well discharges to 1000 m^3/day; 15 - boundaries of areas of stratum, stratum-interstitial and interstitial and interstitial-vein waters.

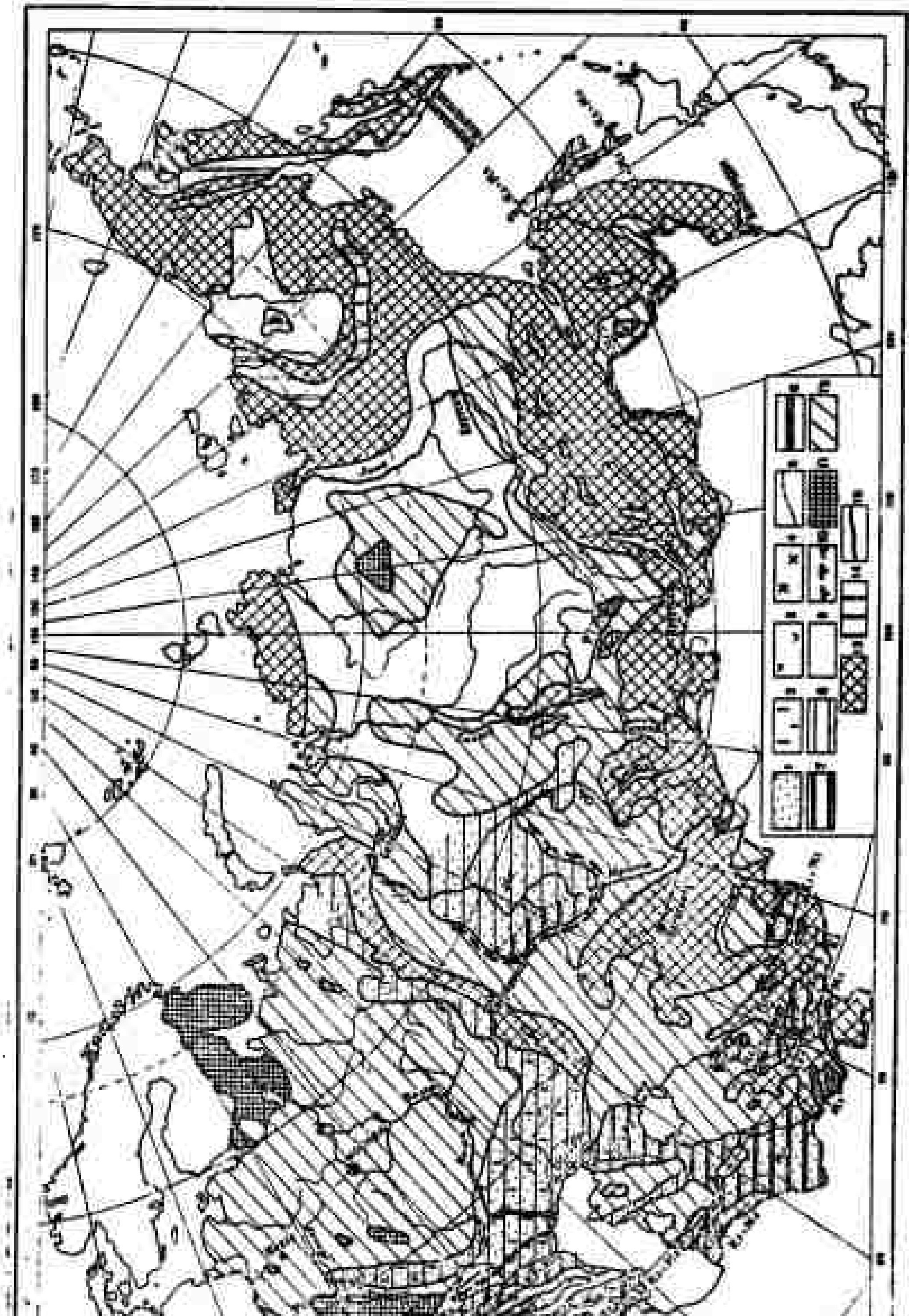
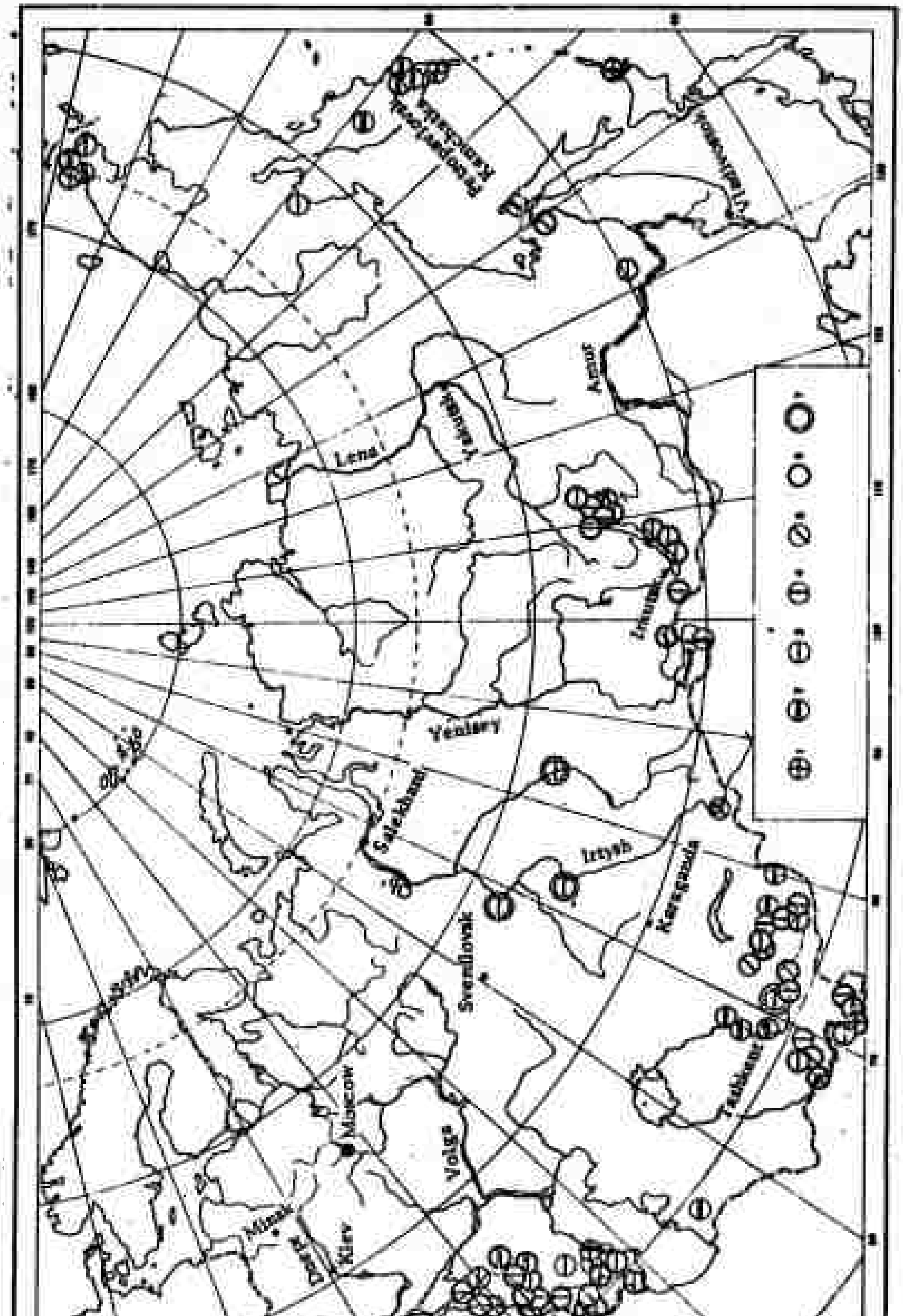


Fig. 16. Schematic Map Showing Water Abundance in Rocks Containing Superheated Water ($100^{\circ}C \pm 10$), i.e., $212^{\circ}F \pm 18$, in the USSR. (p. 72).

<u>Areas of Stratum and Stratum-Interstitial Waters</u>. <u>Water-bearing rocks:</u> (1 - 4): 1 - terrigenous; 2 - carbonaceous; 3 - tufaceous; 4 - saliferous; 5 - contacts between water-bearing rocks of different ages. <u>Water abundance (6 - 9) of rocks</u> (expected well discharges, m^3/day): 6 - exceedingly abundant (mainly above 1000); 7 - abundant (mainly from 250 to 1000); 8 - low abundance (mainly to 250); 9 - regions for which information is lacking; 10 - boundaries of regions in which superheated artesian waters are possible. <u>Areas of Interstitial and Interstitial-Vein Waters</u>: 11 - crystalline shields (occurrence of superheated waters not found); 12 - basements of artesian basins (occurrence of superheated waters not found); 13 - fold-mountain areas (superheated waters found in tectonically disrupted zones with spring and well discharges of up to 1000, occasionally to 1500 m^3/day); 14 - upper structural stages of fold-mountain areas in which interstitial water may occur in small artesian basins (prevailing discharge of wells to 500 m^3/day; 15 - boundaries of areas in which stratum, stratum-interstitial and interstitial and interstitial-vein waters are possible.



Petropavlovsk Kamchatskiy
Vladivostok
Amur
Yakutsk
Lena
Irkutsk
Yeniesy
Salekhard
Irtysh
Karaganda
Sverdlovsk
Tashkent
Moscow
Volga
Minsk
Kiev

Fig. 37. Sketch Map Showing Regions of Potentially Useful High-Temperature Waters. (p. 164).

<u>Practical utilization of high-temperature waters (according to hydrogeological indices)</u>: 1 - geothermal electric power station with subsequent utilization of recycled water for heating, hot-water supply or hothousing-greenhousing; 2 - thermal power installation (utilizing refrigerants) for heating, hot water supply hothousing-greenhousing; 3 - heating, hot-water supply, hothousing-greenhousing; 4 - heating-cooling supply, swimming pools, bath facilities, heating of soil, hot-spring irrigation; 5 - heating-cooling, swimming pools, heating of soil; 6 - thermal energy and balneology; 7 - thermal energy and chemicals manufacture.

Source discharges, m^3/day	Number of Sources																			
	Caucasus				Central Asia & Kazakhstan				Baykal Area				Northeastern Sibiria				Kamchatka & Kurile Islands			
	Total	Temp. ranges, °C 40—60	60—90	>90	Total	Temp. ranges, °C 40—60	60—90	>90	Total	Temp. ranges, °C 40—60	60—90	>90	Total	Temp. ranges, °C 40—60	60—90	>90	Total	Temp. ranges, °C 40—80	60—90	>90
Less than 500	19	15	4	—	20	16	4	—	14	9	5	—	8	7	1	—	10	3	3	4
From 500 to 15000	9	8	1	—	4	3	1	—	6	6	—	—	4	2	2	—	8	1	5	2
From 1500 to 2500	—	—	—	—	1	1	—	—	3	1	2	—	1	—	1	—	—	—	—	—
More than 2500	—	—	—	—	—	—	—	—	2	1	1	—	2	—	1	1	4	—	—	4
Unknown	9	3	5	1	5	4	1	—	7	6	1	—	5	2	3	—	21	7	7	7

Table 2. Discharges of Hot Springs in the USSR. (p. 117).

Borehole site and its number	Depth of sampling, m	Water-bearing rocks: Age	Water-bearing rocks: Composition	Well discharge, nat. artesian, m^3/day	Water temp., °C	pH	Mineralization	Na^++K^+	Mg^{2+}	Ca^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	Trace elements	Freely escaping gases
Novaya Matsesta, T-2	2000	J	Limestones	5600	38,3	6,6	26,9	8,40	0,37	1,37	16,00	0,004	0,59	J, Br, Si, Fe,	
Matsesta, T-2	1660—1760	»	Ditto	2500	38,7	6,6	27,7	8,60	0,36	1,40	16,40	0,003	0,58	Zn, Sr, F, B,	
Staraya Matsesta, T-2	2170	»	» »	490	33,2	6,65	26,9	8,40	0,38	1,33	16,00	0,002	0,53	Mn	H_2S, CH_4
Khosta, T-1	2200	»	» »	1000	45,5	6,5	23,0	7,10	0,34	1,15	13,50	0,01	0,59		
Gagra	2500	$Cr+J_3$	» »	2500	42,0	7,5	2,3	0,06	0,15	0,44	0,15	1,37	0,23		H_2S, N_2
Sukhumi, 1	1800	Cr_1	» »	1000	35,0	7,4	1,7	0,32	0,05	0,12	0,25	0,63	0,27	Br, J, B, Si, Fe	H_2S,N_2
Geshtek, 5A	648	Cr_2	» »	250	62,0	—	4,3	1,51	0,03	0,16	0,34	0,55	3,44		
Dzhermuk	46	»	Limestones, marls	500	64,0	7,3	3,8	1,00	0,07	0,15	0,40	0,90	2,24		CO_2,N_2
Ankavan, 17	262	»	Limestones	1723	39,0	—	6,9	1,85	0,11	0,63	0,06	0,22	3,64		
Istisu	670	Pg	Tuffs	2592	60,0	6,8	5,0	1,70	0,03	0,22	1,06	0,66	2,71	J, Br, Si, Mn, Fe, Al	CO_2
Tbilisi, 5	1058	Pg_2	Sandstones and deposits of volcanic origin	73,4	42,0	8,9	4,4	1,10	0,01	0,58	2,68	0,04	0,10		
Tbilisi, 8	1405	Pg	Argillaceous shales and sandstones	708	50,5	—	0,4	0,10	0,01	0,01	0,07	0,12	0,16	Si, Al, Zn, Fe, Ti, Pb, Cu, Ba, Mn	CH_4, N_2, H_2S
Tbilisi, 9	1009	Pg_2^3	Sandstones and volcanic deposits	1100	56,0	—	0,3	0,09	0,01	0,07	0,04	0,03	0,10		
Borzhomi	194	Pg_1	Flysch deposits	60	32,8	6,9	5,9	1,53	0,04	0,09	0,38	0,003	3,87	Sr, Ba, Fe, Al, Mn, Br, J	CO_2
Bogachevskaya, 6-P	1771—1737	N_2	Shales	To 10	70,0	—	7,3	1,35	0,02	1,02	2,45	1,14	2,27		

*Data of L. N. Barabanov (1961), I. M. Buachidze and S. S. Chikhelidze (1961) were used in compiling the table.

Table 8. Results of Hydrogeological Samplings of Deep Boreholes Disclosing High-Temperature Waters in Small Artesian Basins (p. 123).

Table 15. Key Criteria for the Effective Utilization of High-Temperature Waters as Heat Transfer Agents in Various Branches of the Economy * (p. 153).

Branches of economy	Temp. °C	Discharge, more than m^3/day	Pressure, more than, atm	Depth of waterbearing stratum not exceeding, m	Impurity content not exceeding, mg/l	Mineralization not exceeding, g/l	Hardness not exceeding, mg/eqv	pH	O_2 not exceeding, mg/l	CO_2 (free) not exceeding, mg/l	H_2S (free) not exceeding, mg/l	Period of exploitation not less than, yrs.
THERMAL ENERGY												
Geothermal electric power station	above 100	10000	2,5	5000	5	2—4(50)**	3(9)	5,5—9,5	0,1(0,5)	10(250)	1(10)	25—30
Geothermal energy, utilizing refrigerants	60—90	2500	1,0	2500	5	50	9	"	0,5	50	10	"
MUNICIPAL SERVICES												
Heating	70—90	1000	1,5	2500	5	2(50)	3(9)	"	0,1(0,5)	10(250)	1(10)	"
Hot water supply	40—60	1000	1,5	1500	5	2(50)	3(9)	"	0,1(0,5)	10(250)	1(10)	"
Heating-cooling supply	25—50	500	1,0	1500	5	50	9	"	0,5(0,5)	0	10	"
Swimming pools and baths	25—40	250	1,0	1000	10	50	9(12)	"	—	50(500)	1(10)	"
AGRICULTURE												
Hothouse, greenhouse, conservatory heating	40—70	500	1,0	1500	5	10(50)	5(12)	"	0,5(0,5)	50(550)	1(10)	"
Heating of soils	25—50	500	1,0	1000	5	50	5	"	0,5	50	1	"
Hot-spring irrigation	25—40	250	2,0	1000	10	2	5	"		50	1	"

*When concrete and reinforced concrete are used, it is necessary to take into account sulfate and magnesian aggressive waters (SN 249-63).

**The limiting values of heat exchange in geothermal installations are given in parentheses.

Table 16. Regions of Potential Utilization of High-Temperature Stratum- and Fracture-Waters (pp. 156-160).

BASIC DATA ON HIGH-TEMPERATURE WATERS

Artesian basins	Regions	Water-bearing formations	Depth of occurrence, m	Wellhead water temp., °C	Well discharge, m^3/day	Pressure at wellhead, atm	Mineralization, g/l	Chemical type	Possible kinds of utilization
Transcarpathia	Transcarpathian area								Heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
	Irshavskiy	Sarmatian	450—600	35—40	1000—1500	Flowing well	0,5—2,0	HCO_3—Na	
	Uzhgorodskiy	Neogene	350—500	25—30	400—500	Ditto	0,8—1,5	Ditto	
Black Sea area	Crimea area								
	Yevpatoriya, Novoselovskaya sta., Saki spa, and nearby population centers	Lower Cretaceous	800—1000	35—45	500—2000	" "	1—10	Cl—Na, HCO_3—Na	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
	Simferopol' and environs	Lower Cretaceous	400—600	35—40	500—1000	" "	0,8—1,2	HCO_3—Na	
Azov-Kuban	Krasnodar area								
	Krasnodar and population centers westward along Kuban' R. valley	Paleo-alluvial, Pontian and Kimmeridgian	To 1000	35—40	500—1000	" "	0,5—0,6	HCO_3—Ca	Heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
	Maykop, Kurdzhipskaya, Kushorskaya, and Tul'skaya stations	Oligocene Lower Cretaceous (Albian)	1200—1500 2500—2800	60—70 70—80	500—2000 To 500	To 20 Flowing well	25—30 5—7	Cl—Na Ditto	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing
	Apsheronsk	Lower Cretaceous	2200—2500	75—80	300—500	To 10	25—30	Ditto	Flowing well
	Armavir and environs	Eocene-Paleocene	2600—1700	40—50	500—300	Flowing well	To 20	" "	Heating, hot water supply, hothousing-greenhousing
	Labinsk	Lower Cretaceous	2500—2600	85—90	500—600	Ditto	10—12	" "	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing

Table 16 (con't)

Azov-Kuban									
Tersko-Kumskiy	Belorechenskaya stanitsa, Velikoye Dagestan ASSR	Chokrakian	1100—1200	50—60	400—600	Flowing well	3—5	HCO_3—Na	Heating, hothousing-greenhousing
	Makhachkala, Karaman, Kizlyar, Khasav'yurt	Karaganian-Chokrakian	2500—3000	100—120	1500—3000	5—10 or more	2,5	Ditto	Geothermal electric power station with recycling of water for heating, hot-water supply and hothousing-greenhousing
	Izberbash, Kaspiysk, and nearby population centers	Karaganian	1000—1500	40—60	300—500	1—3	2—5	» »	Heating-cooling supply, swimming pools and bath facilities, heating of soils
	Checheno-Ingushskaya ASSR								
	Groznyy, Gudermes, Goragorsk	Karaganian-Chokrakian	2000—2500	65—85	To 1500	10 or more	1—3	Cl — Na	Heating, hot-water supply, hothousing-greenhousing
	Datykh, Karabulak, Achaluki	Upper Cretaceous	1200—1700	60—80	To 5000	To 20	To 50	Ditto	
	Kabardino-Balkarskaya ASSR								
	Nal'chik and environs	Lower Cretaceous	2200—2300	80—85	600—800	17—20	18—20	Ditto	Ditto
	Stavropol'skiy kray								
	Georgiyevsk and nearby population centers	Miocene-Oligocene	1200—1800	65—90	2000—3000	25—75	To 30	» »	Thermal energy utilizing refrigerants, heating, hot-water supply, hothousing-greenhousing
	Nevinnomyssk, Prikumsk, and nearby population centers	Lower Cretaceous	3000—3200	100—120	500—1000	12—35	20—50	» »	Ditto
	Nagutskaya stanitsa	Lower Cretaceous	1300—1400	50—55	300—500	40—50	0,8—0,9	HCO_3—Na	Hot-water supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation

Table 16 (con't)

BASIC DATA ON HIGH-TEMPERATURE WATERS

Artesian basins	Regions	Water-bearing formations	Depth of occurrence, m	Wellhead water temp., °C	Well discharge, m³/day	Pressure at wellhead, atm	Mineralization, g/l	Chemical type	Possible kinds of utilization
	Cherkessk and environs	Lower Cretaceous	1500—2500	60—90	300—1000	10—20	1—3	HCO_3—Na	Heating, hot water supply, hothousing-greenhousing
	Pyatigorsk, Yessentuki and their environs	Paleocene	1000—1500	35—40	500—2000	15—35	1—8	HCO_3—Na	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Riono-Kurinskiye	Gruzinskaya SSR Zugdidi, Tsaishi [illegible], Tskhakaya, Nakalakevi, Kvaloni, Poti	Upper Cretaceous	2000—3000	75—80	To 600	2—5	1,5—2,5	SO_4—Ca, Cl — Na	Balneology, heating, hot water supply, hothousing-greenhousing
	Azerbaydzhanskaya SSR								
	Mis-Bashir and nearby population centers	Maykopian	1000—1500	35—40	To 500	Flowing well	12—15	Cl — Na	Heating-cooling supply, bath facilities, heating of soils
Syrdar'yinskiy	Kazakhskaya and Uzbekskaya SSR								
	Tashkent, Arys', Sary-Agach, Tainerlanovka, Kibray, Ishavan-Kurgan and nearby population centers	Upper Cretaceous	1400—1600	50—70	To 5000	3—5	0,5—1,5	HCO_3— Na, SO_4— Na, Cl — Na	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing
Western Turkmenia	Turkmenskaya SSR Cheleken peninsula, Nebit-Dag, Krasnovodsk	Pliocene (red beds)	1500—1800	70—80	800—1000	5—10	20—30	Cl — Na	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing, chemical manufacturing

Table 16 (con't)

Ferganskiy	Uzbekskaya SSR Fergana, Chartak, Gur-Tepe and nearby population centers	Neogene (Massagetian stage)	2000—2500	60—70	400—1200	To 12	30—50	Cl — Na	Heating, hothousing-greenhousing, chemical manufacturing
	Fergana, Izbaskent, Vannovskaya sta., Margelan and nearby population centers	Neogene (Bahtrian stage)	1000—1200	40—45	800—1000	To 10	0,7—0,8	HCO_3 — Na	Balneology, heating-cooling supply, swimming pool and bath facilities, heating of soils, hot-spring irrigation
South Tadzhik	Tadzhikskaya SSR Dushanbe, Shaambary and nearby population centers	Neogene	500—1000	40—45	400—500	1—5	1—15	SO_4 — Na	Balneology, heating-cooling supply, bath facilities, heating of soils
	Termez and environs	Paleocene	1000—1500	40—45	400—500	1—5	5—15	Ditto	
Iliyskiy	Kazakhskaya SSR Panfilov and nearby population centers	Cretaceous	2000—2500	80—90	500—1000	To 10	2—5	HCO_3 — Na	Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing
	Alma-Ata and environs	Cretaceous	2500—3000	70—80	500—1000	To 10	2—5	Ditto	
Issykul'skiy	Kirgizskaya SSR Przheval'skiy (Dzhergalan R. valley)	Neogene	1500—1600	40—45	2000—2500	5—10	0,8—1,0	Cl — Na	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Chuyskiy	Kazakhskaya SSR Frunze, Lugovskaya sta. and nearby population centers	Neogene-Paleocene	800—1000	30—40	1000—1500	2—5	1—5	HCO_3 — Na	Heating-cooling supply, bath facilities, heating of soils
Zaysanskiy	Kazakhskaya SSR Zaysan and nearby population centers	Neogene and Paleocene	1200—1500	40—45	To 1000	0—5	1—5	SO_4 — Na	Ditto
West Siberian	Western Siberia Omsk, Tyumen', Tobol'sk and nearby population centers	Lower Cretaceous	1800—2200	65—85	200—800	To 7	To 30	Cl — Na	Heating, hothousing-greenhousing, chemical manufacturing

Table 16 (con't)

BASIC DATA ON HIGH-TEMPERATURE WATERS

Artesian basins	Regions	Water-bearing formations	Depth of occurrence, m	Wellhead water temp. oC	Well discharge, m3/day	Pressure at wellhead, atm	Mineralization, g/l	Chemical type	Possible kinds of utilization
Tunkinskiy	Buryatskaya ASSR Arshan spa and nearby population centers	Neogene	800—1000	35—40	400—600	Flowing well	0,8—1,0	HCO_3—Na	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Selenginskiy	Buryatskaya ASSR Population centers of Selenga r. delta	Neogene	2200—2800	50—60	400—600	Ditto	To 3	HCO_3—Na, Cl—Na	Balneology, heating, hot water supply, hothousing-greenhousing
North Sakhalin	Sakhalinskaya Oblast' Okha, Mukhto and nearby population centers	Neogene	1500—2000	30—35	To 300	» »	5—10	Cl—Na	Heating-cooling supply, bath facilities, heating of soils

BASIC DATA ON HIGH-TEMPERATURE WATERS

Artesian basins	Regions	Temp., oC	Discharge, m3/day	Mineralization, g/l	Chemical type	Gas components	Possible kinds of utilization
Tbilisskiy	Gruzinskaya SSR, Tbilisskiy	45—50	>5000	0,3—0,4	Cl—Na	NH_3	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Aspindzskiy	Adigenskiy	39—40	2000	0,5—0,9	Cl—Na		
Borzhomskiy	Borzhomi spa	36	600	6,0—7,0	HCO_3—Na	CO_2	Balneology, heating-cooling supply, baths, heating of soils
Sukhumo-Kodorskiy	Sukhumskiy (Besleti village)	39—42	2000	1,5—2,6	SO_4—Na		
Gagrinsko-Gudautskiy	Gagrinskiy (Novaya Gagra)	41	2500	2,0—3,0	SO_4—Ca	N_2	
Pambakskiy	Armyanskaya SSR, Ankavanskiy	39	1800	6,9	HCO_3—Na	CO_2	
Arpinskiy	Dzhermuk spa	50—65	2000	3,0—4,0	HCO_3—Na	CO_2	Balneology, heating, hothousing-greenhousing
Kel'badzhanskiy	Azerbaydzhanskaya SSR, Isti-Su spa and environs	40—64	4000—4500	4,5—7,0	HCO_3—Na	CO_2	
Lenkoranskiy	Gornyy Talysh	40—65	6000	2,0—17,0	Ditto	CH_4, CO_2, N_2	

Table 17. Regions of Potential Utilization of Fracture High-Temperature Waters in Small Artesian Basins (p. 160)

Table 18. Regions of Potential Utilization of High Temperature Springs and Their "Parallel" Boreholes (pp. 161-163).

Wells	BASIC DATA ON HIGH-TEMPERATURE WATERS					Possible kinds of utilization
	Temp., °C	Discharge m^3/days	Mineralization, g/l	Chemical types	Gas components	
Azerbaydzhanskaya SSR						
Khaltanskiye	47	1200	1,7	HCO_3 — Na	H_2S	Balneology, heating, hothousing-greenhousing
Tadzhikskaya SSR						
Khodzha-Obi-Garm	40—90	500	0,4—0,5	SO_4 — Na	N_2	Balneology, heating, hot water supply, hothousing-greenhousing, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Obi-Garm	43—45	1500	0,5—0,6	Cl — Na	N_2	
Chashma, Yamchin	43	630	0,8	SO_4 — Na	H_2S	Balneology, heating, hothousing-greenhousing, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Dzhilandy	60	480	0,2	HCO_3 — Na	—	
Tokuz-Bulak	65	450	0,4	SO_4 — Na	CO_2	
Garm-Chashma	64	650	1,8	HCO_3 — Na	Ditto	
Dzharty-Gumbez	63	260	1,8	HCO_3 — Na	H_2S, CO_2	
Issyk-Bulak	65	61	1,1	HCO_3 — Na	CO_2	
Kirgizskaya SSR						
Dzhalal-Abad	43	500	1,6	SO_4 — Na	N_2	Balneology, heating-cooling supply, baths, heating of soils
Issyk-Ata	56	1555	0,3	SO_4 — Na	Ditto	Heating, hot water supply, hothousing-greenhousing, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Ak-Su	41—56	1600	0,3—0,4	HCO_3 — Na	» »	
Dzhely-Su-Kadzhi	52	1280	0,9	SO_4 — Na	» »	
Dzhety-Oguz	44	500	13,0	Cl—Ca—Na	» »	Balneology, heating-cooling supply, baths, heating of soils
Kazakhskaya SSR						
Alma-Arasan	37	520	0,25	SO_4 — Na	N_2	Balneology, heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Tuvinskaya avtonomnaya oblast', Tayrys	47	600	0,4	SO_4 — Na	N_2	Heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation

Table 18 (con't)

BASIC DATA ON HIGH-TEMPERATURE WATERS

Wells	Temp., °C	Discharge m^3/days	Mineralization, g/l	Chemical types	Gas components	Possible kinds of utilization
Yush-Bel'dyr (wells and holes)	80	500	0,4	SO_4 — Na	—	Balneology, heating, hot water supply, hothousing-greenhousing
Buryatskaya ASSR						Thermal energy utilizing refrigerants, heating, hot water supply, hothousing-greenhousing
Mogoyskiye	82	7000	0,4	HCO_3 — Na		
Uakitskiy	78—82	7000	0,6	SO_4 — Na	—	
Hot springs and wells						Balneology, heating, hot water supply, hothousing-greenhousing
Verkhneangarakanskiye	56	2000	0,6	SO_4 — Na	N_2	
Bauntovskiye	59	6000	0,3	HCO_3 — Na	Ditto	
Kotel'nikovskiye	54	1200	0,35	HCO_3 — Na	» »	
Garginskiye	62	1730	0,3	SO_4 — Na	» »	
	75	200	1,0	Ditto	» »	
Pitatelevskiye (wells, boreholes)						
	54—68	>1000	1,5—2,0	» »	» »	
Shurinda	40—60	1700	0,5	» »	» »	
Seyuyskiye	52—55	400	0,3	» »	» »	
Irkanskiye	37	900	0,3	SO_4 — Na	N_2	Heating-cooling supply, swimming pools and bath facilities, heating of soils, hot-spring irrigation
Dzhilinda	42	—	0,2	Ditto	Ditto	
Korikeyskiye	44	1000	0,3	» »	» »	
Magadanskaya oblast'						Balneology, heating, hot water supply, hothousing-greenhousing
Tavatumskiye	58	865	15,0	Cl — Na	CH_4	
Kabarovskiy kray						
Annenskiye	51	450	0,3	HCO_3 — Na	N_2	
Kul'dur	72	1900	0,3	Cl — Na	—	
Chukotskiy national'nyy okrug						Heating, hothousing-greenhousing
Kukun'skiye	61	3500	4,5	Cl — Na	CO_2, N_2	
Neshkenskiye	55	740	35,0	Ditto	CH_4	
Mechigmenskiye	95	6500	3,9	» »	CO_2, N_2	Thermal power utilizing refrigerants, heating, hot water supply, hothousing-greenhousing
Senyavinskiye	79	1120	1,5	» »	—	
Chaplinskiye	80	1280	18,0	» »	—	
Gil'mimlineyskiye	85	4300	3,0	» »	—	

Table 18 (con't)

BASIC DATA ON HIGH-TEMPERATURE WATERS

Wells	Temp., °C	Discharge m^3/days	Mineralization, g/l	Chemical type	Gas components	Possible kinds of utilization
Kamchatskaya oblast'						Ditto
Zhirovskiye	99	2590	0,8	» »	N_2	
Kireunskiye	100	3400	1,6	» »	N_2, CO_2	
Bannyye	97	3000	1,2—1,4	SO_4 — Na	N_2	
Paratunskiye (springs and wells)	64 (spr.) 64—87 (wells)	200 7000	1,3—1,9	Ditto	Ditto	
Pauzhetskiye (springs and wells)	100—200	To 10000	2,7—3,4	Cl — Na	CO_2, N_2	Geothermal power station with re-use of recycled water for heating, hot water supply, and hothousing-greenhousing
Kurile Islands, Goryachiy Klyuch	100—130	Not precisely determined, having latent discharge of water and escaping dry air jets and steam	4,6	Cl — Na	N_2, CO_2, NH_4	Ditto

Section B.

* While not stated in text, the implication here is that for some natural springs, an additional borehole is sunk to the deep source in an effort to increase the output.

Fig. 31. Variation in Temperature in Various Areas of the Earth's Crust and the Temperature of Saturated Steam as a Function of Depth and Pressure. (p. 144).

HEAT REGIME OF THE EARTH'S INTERIOR IN THE USSR

Akademiya nauk SSSR. Geologicheskiy institut. Teplovoy rezhim nedr SSSR (Heat regime of the Earth's interior in the USSR). Moscow, Izd-vo Nauka, 1970, 224 p. (ITS: Trudy, no. 218, 1970).

The above cited work, while structured as a monograph, is basically a collection of individually authored or coauthored chapters or sections. Following the translated table of contents, the book is grouped into informative and indicative sections and the original numeration has been retained. Worthy of special note are two large fold-in maps which show the geothermal gradient in the upper part of the earth's crust in the USSR (Fig. 12) and the distribution of temperature at the surfaces of the crystalline and folded basements in the USSR (Fig. 13). The large volume of map information on area geothermal gradients, contained on the map in Fig. 12 (scale-approximately 1:20,000,000) also shows permafrost isopachs (lines of equal permafrost thickness) for the 100-, 300-, and 500-meter thicknesses.

Table of Contents

References: Contains 300 references, 204 of Soviet origin and 96 of non-Soviet origin.

Section A.

(continued with map on next page)

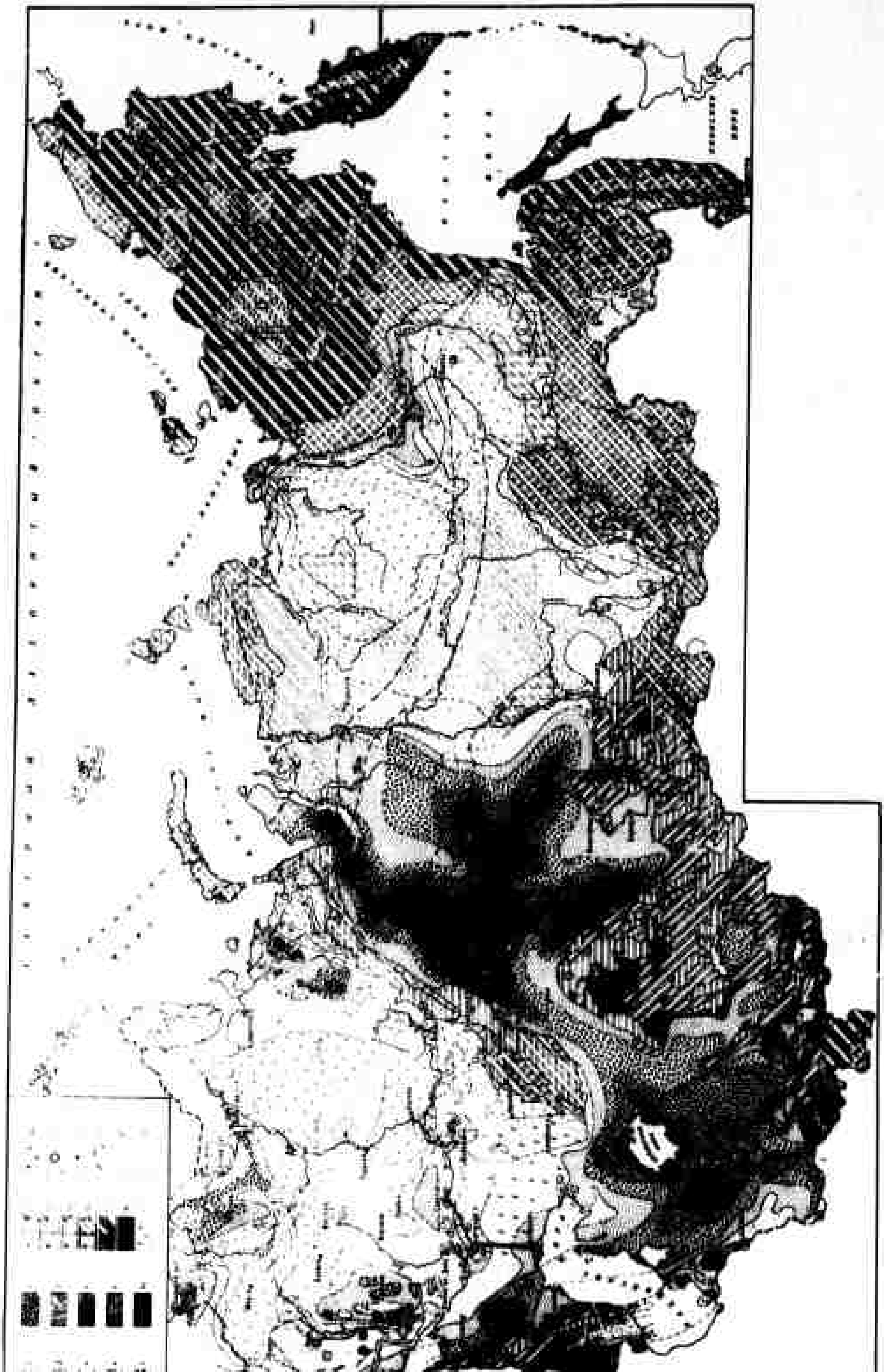
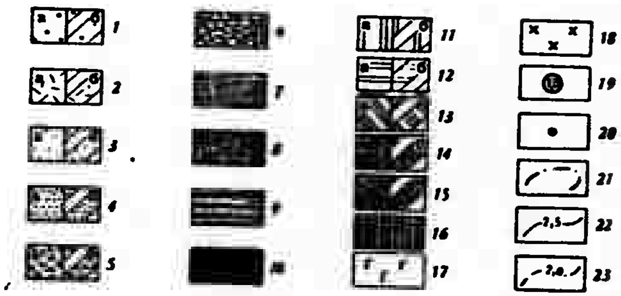


Fig. 12. Map of the Geothermal Gradient in the Upper Part of the Earth's Crust in the USSR Territory(Schematic map compiled by several authors and edited by F. A. Makarenko, B. G. Polyak and Ya. B. Smirnov, issued in 1965 and revised in 1967. Scale: approximately 1:20, 000, 000). (insert between pp. 76-77).

Zones in which the predominant gradients, in °C/100m, in areas covered by platform and partially by orogenic formations within the boundaries of the sedimentary regolith down to a depth of 3000 m are: 1 - less than 1.5 (here a are determined values and b are postulated); 2 - 1.5 to 2.0; 3 - 2.0 to 2.5; 4 - 2.5 to 3.0; 5 - 3.0 to 3.5; 6 - 3.5 to 4.0; 7 - 4.0 to 4.5 ;8 - 4.5 to 5.0; 9 - 5.0 to 6.0; 10 - more than 6.0. Zones in which the predominant gradients in °C/100m, in areas covered by geosynclinal and partly orogenic formations within the boundaries of an identified structural stage are: 11 - less than 1.0; 12 - 1.0 to 1.5; 13 - 1.5 to 2.0; 14 - 2.0 to 2.5; 15 - 2.5 to 3.0; 16 - more than 3.0. Zones in which the geothermal gradient varies sharply are: 17 - areas of salt-dome tectonics; 18 - areas of Quaternary volcanism; 19 - determined values of the thermal gradient at the basement of platforms and geosynclinal areas; 20 - characteristic positive anomalies in the geotemperature field; 21 - permafrost isopachs; i.e., lines connecting points of equal permafrost thickness . Isogradients:22 - determined; 23 - postulated.



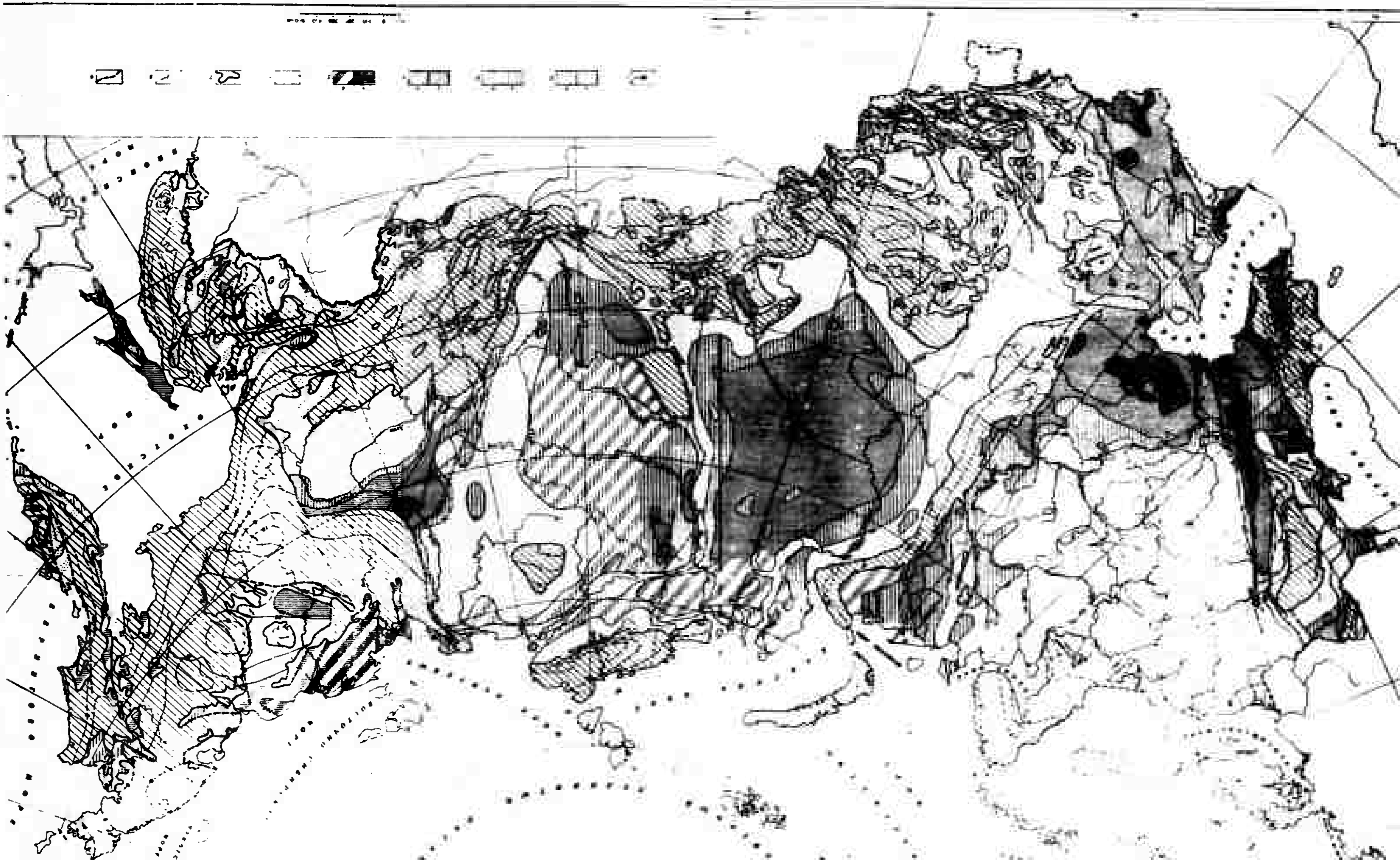


Fig. 13. Map Showing the Distribution of Temperatures at the Surfaces of the Crystalline and Folded Basements in USSR Territory (Schematic map compiled by several authors under the editorship of F. A. Makarenko, issued in 1963 and revised in 1967. Scale: approximately 1:15,000,000). (insert between pp. 76-77).

1 - eoisotherms at the surface of the crystalline and folded basements of platforms, plates and major marginal and intermontane troughs; 2 - 5 geothermal zones on the surface of crystalline and folded basements (a - determined, b - postulated): 2 - lower than 50°C; 3 - 50-100°C; 4 - 100 to 200°C; 5 - higher than 200°C; 6 - fold-mountain areas and crystalline massifs; 7 - boundaries of fold-mountain areas and crystalline massifs; 8 - temperature of the "neutral" layer in fold-mountain areas and crystalline massifs; 9 - faults.

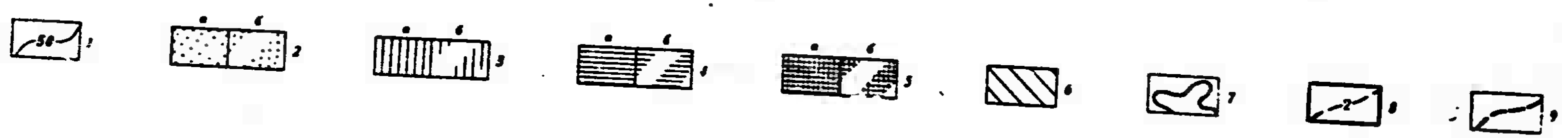


Table 20. Distribution of Temperatures in the Sedimentary Regolith of Precambrian Platform (in the numerator - minimum and maximum values, in the denominator - average values). (pp. 86-87).

Region	Temperatures (°C) at depths (m)						Thickness of permafrost, m	Max. depth of basement, m	Temp. at these depths, °C	Average temp. gradient, °C/100m	Depth (m) of isotherm occurrence	
	500	1000	1500	2000	2500	3000					50°	100°
RUSSIAN PLATFORM												
Volga-Ural anteclise	$\frac{5-28}{16}$	$\frac{13-38}{24}$	$\frac{19-51}{34}$	—	—	—	—	1050—2300	20—53	$\frac{0,7-2,9}{1,8}$	1470—1870	—
Moscow syneclise	$\frac{7-16}{13}$	$\frac{10-24}{18}$	$\frac{14-42}{29}$	$\frac{17-56}{41}$	—	—	—	5000	50	$\frac{0,7-2,7}{1,6}$	1680—3600	—
Pechora syneclise	$\frac{7-22}{14}$	$\frac{14-38}{27}$	$\frac{26-54}{38}$	$\frac{34-74}{55}$	$\frac{57-83}{69}$	$\frac{47-111}{84}$	—	7000	150	$\frac{1,3-4,1}{2,7}$	1330—3230	2890—3960
Caspian foreland depression	$\frac{13-42}{28}$	$\frac{23-51}{36}$	$\frac{30-62}{45}$	$\frac{31-77}{52}$	$\frac{33-85}{59}$	$\frac{35-107}{66}$	—	15500	200	$\frac{0,5-3,7}{2,0}$	970—3400	—
Pripet downwarp	$\frac{10-23}{15}$	$\frac{17-35}{22}$	$\frac{24-47}{31}$	$\frac{30-54}{37}$	$\frac{38-65}{49}$	$\frac{40-67}{51}$	—	5000	100	$\frac{1,0-2,0}{1,4}$	1720—4000	—
Dnieper-Donets downwarp	$\frac{13-30}{23}$	$\frac{22-49}{38}$	$\frac{35-64}{48}$	$\frac{49-84}{63}$	$\frac{55-99}{76}$	$\frac{67-119}{90}$	—	8000	200	$\frac{1,4-3,5}{2,7}$	1040—3040	2470—5400

Table 20 (con't)

SIBERIAN PLATFORM

North slope of Aldan shield		3—4 / 3,5	10,5	—	—	—	—	80—100	1500—2500	20—25	0,7—1,3	—	—
Tunguss syneclise	Noril'sk region	4—13 / 8	15—25 / 20	27—37 / 32	38—48 / 43	—	—	30—70	4500—5500	96—105	2,3	2100	5500—5300
	Tunguss boreholes	4	13	22	31	40	49	90	4500	76	1,8	3050	
Monocline of NE slope of E. Sayan and S. part of the Baykal foreland arched uplift area		6—13 / 11	13—19 / 15	19—25 / 22	26—31 / 28	32—44 / 39	—	—	2700—2800	38—47	1,4	—	—
Central part of Baykal foreland arched uplift and and central field of Irkutsk amphitheater		13—19 / 15	21—28 / 25	28—31 / 29	32—36 / 35	39—42 / 40	—	—	3800—4000	67—74	1,5	3250—3050 / 3100	—
Kansko-Taseyev depression		15—16,5 / 16	22—26 / 24	30—37 / 34	40—51 / 45	46—67 / 54	57—78 / 62	—	5500—7000	100—135	1,7—2,5	2750—2650 / 2700	5500—4500 / 6000
Rybinsk depression		16	28	39	51	62	—	—	2000—2500	>60	2,3	2000	—
Vilyuy syneclise		0—9 / 3	10—21 / 14	22—34 / 28	34—47 / 42	46—63 / 55	55—83 / 68	До 650	6000—9000	150—250	1,6—4,0	2200—2600 / 2400	3500—4100 / 3800

Table 22. Distribution of Temperatures in the Sedimentary Regolith of Epi-Paleozoic Plates (in the numerator - minimum and maximum values, in the denominator - average values). (pp. 92-93).

Region		Temp. (°C) at depths (m)						Max. depth of basement, m	Temp. at these depths, °C	Average heat gradient, °C/100m	Depth of occurrence (m) of isotherms	
		500	1000	1500	2000	2500	3000				50°	100°
WEST SIBERIAN PLATE												
Central part of plate		15—28 / 22	27—44 / 34	43—63 / 50	56—96 / 68	72—101 / 84	85—122 / 116	3100—3200	93—126	3,0—5,0	1200—1770 / 1500	2100—2500 / 2300
N. part of plate (Ob'-Tazov interfluve)		7—16 / 11	17—34 / 25	36—52 / 42	50—69 / 58	63—71 / 67	77—84 / 80	3500—4000	100—125	2,5—3,0	1500—2000 / 1750	2900—3850 / 3400
E. Ural slope	S. part	17—40 / 21	31—54 / 42	54—80 / 64	75—93 / 86	—	—	2000—2400	80—116	4,0—6,0	700—1200 / 950	1500—2000 / 1750
	N. part	8—16 / 12	29—38 / 33	51—61 / 54	69—84 / 77	—	—	2000—2500	75—85	3,9—4,7	1140—1500 / 1336	—
N. Kazakhstan slope	Central part (Pavlodar-Irtysh area)	23—33 / 27	43—58 / 52	63—85 / 77	—	—	—	1500—1800	82—102	3,5—6,0	810—1300 / 1050	1800—1900 / 1850
	Western part	20—21 / 20	32—40 / 33	—	—	—	—	1300—1400	53—55	2,4—3,8	—	—
Yenisey foreland slope	S. part	6—14 / 10	17—25 / 22	33—38 / 35	—	—	—	1200—1700	33—39	2,2—3,0	—	—
	N. part	4—10 / 7	16—25 / 21	28—40 / 35	40—58 / 50	52—76 / 66	—	2800—3000	79—87	2,0—3,0	1770—2460 / 2100	—

Table 22 (con't)

TURANSK PLATE

Central Karakum area	Dome part	40—58 / 46	56—69 / 61	70—81 / 77	93—96 / 94	—	—	To 2300	[illegible]	3,1—4,1	300—800 / 550	2100—2200
	S. slope	35—40 / 38	51—56 / 53	66—72 / 68	82—89 / 84	97—100 / 100	113—122 / 117	3500	138	2,9—3,3	800—1000 / 900	2500
Aral area (E. Aral depression)		30—32 / 31	51—54 / 52	71—73 / 72	—	—	—	To 1700	72	3,3—4,3	920—950	—
N.-Ust'yurt-Chelkar zone of downwarps[1]		22—26 / 24	33—43 / 38	45—50 / 51	76	92	108	6000	>250	2,5—3,3	1200—1700	2700
S. Mangyshlak downwarp		30—36 / 33	45—52 / 50	59—71 / 68	74—91 / 87	—	—	To 4000	>150	3,4—4,0	850—1150 / 1000	2300
Bukhara-Khibiny "step" zone		34—42 / 39	50—62 / 56	66—82 / 72	82—102 / 90	100—109 / 104	114—122 / 118	To 5000	>150	3,0—4,3	600—1000 / 800	2000—2500
Bakharod peripheral platform monocline		27—33 / 31	38—47 / 43	48—62 / 55	55—76 / 67	62—91 / 77	70—116 / 88	7300—7500	100—200	2,3—3,3	—	—
Chu syneclise		26—29 / 28	42—50 / 47	59—70 / 65	76—90 / 84	—	—	2400—3000	92—118	3,2—4,0	1000—1200 / 1100	—
Syndar'ya and T-zilient depressions		29—36 / 32	45—58 / 51	62—81 / 70	85—104 / 92	107,5	—	2700—3000	120—130	3,2—4,5	800—1150 / 1000	1000—2300 / 2100
Murgab depression (S. side)		30—33 / 32	46—50 / 48	63—67 / 65	80—84 / 82	97—101 / 99	113—118 / 115	About 4000	До 140	3,3	1000—1200	2400—2500

SKIF PLATE

Azov-Kuban and Tersko-Kum depressions	19—59 / 36	31—84 / 52	47—111 / 70	62—124 / 86	70—140 / 108	79—167 / 115	5500	150	1,4—5,2 / 3,2	500—1680	1300—4400
Stavropol' uplift	25—56 / 40	41—83 / 63	55—110 / 82	66—124 / 99	—	—	1800—2000	50—130	2,0—6,6 / 4,0	520—1350	1330—2540

([1]The data characterize the northwestern and northern marginal portions of the downwarps.)

Table 23. Temperature Distribution in the Upper Structural Stage of Folded Structures (in the numerator - minimum and maximum values, in the denominator - average values). (pp. 94-96).

Stage of folding	Structures		Temp. (°C) at depths (m)						Max. depths of basement, m	Temp. at these depths, °C	Average temp. gradient, °C/100m	Depth of occurrence (m) of isotherms	
			500	1000	1500	2000	2500	3000				50°	100°
Paleozoic	S. Minusinsk depression		15–22 / 18	22–35 / 29	34–58 / 42	40–64 / 54	56–82 / 70	56–97 / 84	5000–7000	130–160	1,4–3,1	1000–2200	2100–5000
	Kuznets downwarp		15–23 / 18	22–38 / 29	29–52 / 40	35–67 / 52	54–91 / 68	65–95 / 80	6000–8000	>200	1,3–2,8	1100–3100	2250–4500
	Zeya-Burein depression		15	30	46	61	77	92	To 3000	92	3,1	1600–1700	—
	Ural foreland marginal downwarp		6–20 / 14	13–24 / 21	22–30 / 27	31–34 / 35	39–49 / 44	45–58 / 51	N. part to 5000, S. part to 15000	To 70 >300	1,0–1,8 / 1,5	2700–3500	—
	Greater Donbas		14–30 / 22	23–47 / 35	31–63 / 50	40–78 / 60	53–98 / 78	55–114 / 84	>9000	>200	1,5–3,2 / 2,4	1100–2700	2250–6000
	Khatanga downwarp	E. edge (Nordvik region)	0,0–0,2 / 0,1	10–12 / 11	19–25 / 22	29–37 / 32	33–50 / 42	48–62 / 56	5000–6000	85–100	2–2,5	2500–3100 / 2800	3200–6000
		W. edge (Ust'-Port region)	5–10 / 8	19–25 / 22	33–40 / 37	42–55 / 51	70	—	2800–3000	70–82	—	1400–2000 / 1800	—
Mesozoic	Borgoyak depression		18	28	41	—	—	—	To 2000	To 53	2,3	—	—
	Verkhoyansk foreland marginal downwarp		0–9 / 2	10–21 / 14	19–34 / 26	29–47 / 38	38–64 / 51	48–80 / 64	9000	>300	1,5–4,0	2200–2800	About 4000

[1]Thickness of permafrost to 400-600 m.

Table 23 (con't)

Stage of folding		Structures	Temp. (°C) at depths (m)						Max. depths of basement, m	Temp. at these depths, °C	Average temp. gradient, °C/100m	Depth of occurrence (m) of isotherms	
			500	1000	1500	2000	2500	3000				50°	100°
Cenozoic	Albian	Rion depression	24—36 / 27	34—46 / 39	43—61 / 51	52—77 / 62	64—91 / 74	74—107 / 84	>8000	160—200	1,8—3,1 / 2,2	1800—1900	About 2700
		Kurinsk depression	22—37 / 27	32—59 / 44	42—83 / 63	51—103 / 78	61—125 / 97	71—148 / 110	>14 000	>300	2,0—4,5 / 3,3	—	—
		Indolo-Kuban marginal downwarp	23—43 / 27	32—59 / 41	46—66 / 57	54—92 / 73	80—107 / 86	74—129 / 100	10000—11000	200—300	2,0—4,5	1000—1750	2130—4300
		Tersko-Caspian downwarp	26—68 / 42	39—75 / 54	56—89 / 67	67—98 / 81	93—113 / 98	89—130 / 106	9000—10 300	>250	1,8—3,7	425—1235	2110—3500
		W. Turkmen depression	22—34 / 30	37—43 / 43	52—62 / 56	64—76 / 68	70—90 / 79	86—104 / 93	14000—15000	280—310	2,1—2,9	500—1800	2800—3600
		Kopetdag foreland marginal downwarp	27—30 / 28,5	36—42 / 39	45—49 / 47	54—60 / 57	65—74 / 69	74—84 / 79	To 10 000	>200	1,8—2,2	1550—1800	—
	Tikhookeanskiy (Pacific Ocean)	West Kamchatka downwarp	24	33—38 / 36	42—52 / 47	50—65 / 58	—	—	>3000	>75	2,8	1470	3400
		East Kamchatka downwarp	22—26 / 24	29—42 / 35	49—56 / 52	63—71 / 67	—	—	—	—	2,8	1300—1530 / 1415	2970—3350 / 3160
		West Sakhalin synclinorium	20—25 / 23	32—40 / 36	55,0	70,0	—	—	To 6000	>200	2,5—3,0	—	—
		East Sakhalin synclinorium	10—19 / 34	21—36 / 30	36—53 / 46	57—64 / 60	—	—	To 6000	>200	2,4—3,4	—	—

Table 23 (con't)

Stage of folding	Structures	Temp. (°C) at depths (m)						Max. depths of basement, m	Temp. at these depths, °C	Average temp. gradient, °C/100m	Depth of occurrence (m) of isotherms	
		500	1000	1500	2000	2500	3000				50°	100°
Cenozoic Neotectonic	Pamir-Alai foothills (Surkhandar'ya, Kulyab depressions)	28—31 / 30	36—46 / 41	50—69 / 59	73	87	100	>7000	>150	2,2—3,0	1200	3000
	Kushkin group of uplifts	38—46 / 42	56—69 / 62	73—92 / 82	91—115 / 103	108—118 / 112	125—138 / 130	4000—5000	160—200	3,5—4,0	600—850	1700—1800
	Fergana depression	25—37 / 32	38—52 / 44	32—68 / 58	62—84 / 70	79—100 / 88	90—116 / 105	>10 000	>250	2,0—3,2	1100—1600 / 1350	2500—3000 / 2750
	Ili depression	16—24 / 19	28—37 / 32	39—49 / 46	50—64 / 59	62—76 / 69	74—91 / 82	2500—4000	70—120	2,3—3,0	1550—2000 / 1700	3300
	Issyk-Kul' depression	20	36	52	68	—	—	About 2000	68—70	3,2	1500	—
	Zaysan depression	21	34	46	—	—	—	About 1500	46	2,5	—	—
	Tunkin depression	15	23	40	53	—	—	3000	76	2,0	950—1900	—
	Selengin depression	13—22	22—34	30—45	46—64	—	53—71	4000	100—125	2,0—2,9	1564	—
	Bargruzin depression	9	24	44	—	—	—	1400	38	2,7	—	—

Much of the information directly pertinent to the development of geothermal areas is concentrated in Chapter V and specifically, in the section entitled "Geothermal Resources of the USSR". In the brief introductory remarks to this section, the authors cite the following major sources containing data on USSR thermal water resources: the transactions of the First All-Union Conference on Geothermal Research, published as "Problemy geotermii i prakticheskogo ispol'zovaniye tepla Zemli" (Problems in geothermy and the practical utilization of the Earth's heat, vol. 1, 1959 and vol. 2, 1961): other All-Union geothermy conferences with the resultant publications "Geotermicheskiye issledovaniya i ispol'zovaniye tepla Zemli" (Geothermal research and the utilization of the Earth's heat, 1966) and "Regional'naya geotermiya i rasprostraneniye termal'nykh vod v SSSR" (Regional geothermy and the distribution of thermal waters in the USSR, 1967); and specialized monographs such as "Otsenka resursov i perspektivy ispol'zovaniya termal'nykh vod SSSR kak istochnika tepla" (An evaluation of resources and prospects for the utilization of USSR thermal waters as a heat source, 1st edition in 1957 and 2nd edition in 1959) and "Termal'nyye vody SSSR i voprosy ikh teploenergeticheskogo ispol'zovaniya" (Thermal waters of the USSR and problems in their utilization for heat and power, 1963).

Distribution of Thermal Waters

The USSR is subdivided into nine regions in terms of hydrogeological and geothermal conditions, each subdivision offering different potentials for the utilization of thermal waters.

1. a) Volcanic regions of Cenozoic eugeosynclines and areas of Cenozoic activity (Kamchatka and the Kurile Islands - Pauzhetka, the Geyzer valley [Dolina Geyzerov], and Goryachiy Plyazh, directly associated with active volcanos;

b) Areas associated with active volcanos (Lesser Caucasus, Tranbaikalia, and northeastern USSR, and such as found in the Nalychevskiye hot springs in Kamchatka, the Dzhermuk spring in Armenia, etc);

2. Mountain structures of the Cenozoic miogeosynclines and areas of epiplatform orogeny (represented by the Carpathians, Greater Caucasus, Pamirs, Tien-Shan, Pribaykal'ye, etc., and at such sites as: the Khadzhi-Obi-Garm springs in the Tien-Shan; the Garm-Chashma, Dzhilandy, and Issyyk-Bulak areas of the Pamirs; the Mogoyskiye, Seyyuyskiye, Allinskiye, Pitatelevskiye springs in the Baykal folded system; and the Yelisu, Khaltanskiye springs in the Greater Caucasus);

3. Cenozoic marginal and interior troughs and neotectonic depressions (Caucasus foreland, and the Fergana, Rion and Kurin depressions);

4. Mesozoic folded mountain structures (Verkhoyansk folded zone, Sytygan-Sylba hot springs in the upper reaches of the Indigirka river);

5. Mesozoic troughs and depressions (the Verkhoyansk foreland downwarp, the Zeysko-Udskaya depression);

6. Paleozoic fold-mountain structures (Urals, the Altay);

7. Regolith of the Paleozoic plate (Skif, Turansk, West Siberia);

8. Precambrian shields (Baltic, Ukrainian, etc.);

9. Regolith of the Precambrian platforms (Russian and Siberian), i.e., Irkutsk basin of the Siberian platform, the Caspian, Dnepr-Donets and Vilyuy depressions.

Uses of Thermal Waters

Here, the authors examine possible uses of thermal waters in specific regions, taking into account engineering and economic considerations based on the particular use (see Table 36).

1. Geothermal energy. The authors mention that the basic design for a geothermal power station was described in the 1960 book "Geotermicheskiye resursy i ikh energeticheskaye ispol'zovaniye" (Geothermal resources and their energy utilization) by B. M. Vymorkov and N. L. Putnik. This

design, however, caused degradation of the steam parameters before the turbine with a resultant reduction of power output per unit of steam. Based on the above source and other data, basic engineering criteria were developed and are summarized in Table 36.

Type of utilization	Temp., °C, not lower than	Discharge, m^3/day, not less than	Depth of occurrence [illegible]	Mineralization, g/l not more than
Generation of electric power by GEOTES** using direct steam-water cycle.............	100	10 000	3000	4
Generation of electric power by GEOTES** using intermediate low-boiling-point substances..................................	70	2500	2500	50
Heat supply of population centers............	70	1000	2500	2 (50)*
Cooling supply..........................	70	500	1500	50
Hot-water supply.......................	40	1000	1500	1 (50)
Greenhousing-hothousing............................	40	500	1500	10 (50)
Hot-water irrigation......................	25	250	1000	2
Warming soil............................	25	500	1500	50
Melting permafrost......................	25	250	3000	50
Swimming pools and bath facilities..........	35	250	1000	50

*In parentheses, allowable mineralization of water for geothermal equipment utilizing heat exchangers.
**Geothermal electric power station

Table 36. Engineering Criteria Used in Identifying the Practical Utilizations of Thermal Waters with a Projected Exploitation Period of 25 Years or More (p. 203).

Studies have been carried out in recent years to find sites for new power stations (other than the Pauzhetka station) by such scientists as V. V. Aver'yev, Ye. A. Vakin, K. F. Bogoroditskiy, B. A. Beder, A. S. Dzhamalova, V. V. Ivanov, B. F. Mavritskiy, F. A. Makarenko, V. M. Sugrobov, and G. M. Sukharev, and others, in regions of active volcanism.

In the Kamchatka area, there are four geothermal regions whose energies are suitable for the construction of geothermal electric power stations (see Table 37).

Geothermal regions and sites	Heat transfer agent	Max. temp., °C	Natural heat capacity, 10^6 cal/sec	Capacity increase factor	Predicted capacity	
					Thermal, 10^6 cal/sec	Electrical, Mw
Pauzhetskiy						155
Pauzhetskoye	s/w*	150—200	15	5 ( )	75	20 (30)
Koshelevskoye	steam	155	75	3	225	135
Uzone-Semyachinskiy **						270
Nizhne-Semyachinskoye	s/w	100	25	3	75	30
Verkhne-Semyachinskoye	steam	136	50	3	150	90
Uzonskoye	s/w	250	60	3	180	90
Mutnovsko-Zhirovskiy						36
Nizhne-Zhirovskoye	s/w	130	4	3	12	3
Verkhne-Zhirovskoye	steam	120	3,5	3	10,5	6
Severo-Mutnovskoye	s/w	130	15	3	45	27
Bol'she-Bannoye	s/w	150—170	5,6	6	30	—

*Steam-water mix
**Without consideration of the Valley of Geysers hot springs

Table 37. Energy Parameters of Geothermal Sites in Kamchatka (after Ye. A. Vakin, 1968). (p. 205).

Other areas which are recommended for investigation to determine their potential use for geothermal electric power stations are listed as being in the East Caucasus foreland (Tersko-Caspian trough and Tersko-Kum depression, near the cities of Makhachkala, Khasavyurt, Kizlar, etc.).

Areas in which the hydrothermal systems have temperatures in excess of 100°C (at attainable depths) but are not suitable for use as geothermal electric power stations occur in the Tersko-Kum basin (too highly mineralized) and in the Khodzha-Obi-Garm area [sic] area (too low discharge, i.e., 1500 m^3/day.

Lower-temperature sources are capable of supplying electric power to industry using ground water at temperatures of less than 100°C. An experimental power station (750 kilowatts) operating on freon-12 is now in operation in Kamchatka at the Sredne-Paratunka wells. Regions

having similar potentials are mentioned as existing at Maykop, the villages of Kurdzhipskaya, Kuzhorskaya, Tul'skaya in the Azov-Kuban artesian basin, at Georivevsk, Nevinnomyssk, Prikumsk in the Tersko-Kum basin, at Tashkent, Sary-Agach in the Syrdar'ya basin, at Krasnovodsk, Nebit-Dag, the Cheleken peninsula in the Western Turkmen basin, and at Alma-Ata and Panfilov in the artesian basin of the Ili depression. In addition, prospects are good for the construction of geothermal electric power stations of this type in the fracture waters of the northeastern USSR - the Mogoyskiye and Uakitskiye hot springs in the Buryat ASSR, and at the Mechigmenskiye, Sinyavinskiye and Chaplinskiye springs in the Chukotskiy National'nyy Okrug.

2. Heat supply for population centers. Plans are being developed at the present time for hot-water pipes to run from the Paratunka springs to Petropavlovsk-Kamchatka, a distance of 45-65 km.

The population centers in the USSR where hot water can be used for heating purposes include Armavir, Groznyy, Gudermes, Nal'chik, Cherkessk, Omsk, Tyumen', Tobol'sk, Arshan, Poti, Tsaishi, Fergana, Chartak, and others.

3. Utilization of thermal waters for cooling purposes. Uses in the chemical industry for refrigeration are possible in regions 1 - 3 and 7 as listed under "Distribution of Thermal Waters" above. The use of thermal waters for air-conditioning may be suitable in such cities as Tashkent, Dushanbe, Alma-Ata, and Frunze.

4. Hot-water supply. Here, the chemical composition of usable water becomes the limiting factor (regulated by State Standard GOST 2874-54), with hot-water supply possible in regions 1 - 3 and 7 as described above.

5. Hothousing - greenhousing. Experiments have been carried out in Kamchatka, Kazakhstan and the Caucasus foreland area. Besides these areas, it is stated that at the present time, the largest hothousing-greenhousing complex in the world is being completed at the Sredne-Paratunka springs; its withdrawal area is 60,000 square meters. Another complex is projected for the Pauzhetka springs (serving 150,000 m^2) with others planned in Dagestan at Makhachkala and Khasavyurt, in the Checheno Ingushskoy ASSR, in the Groznyy area,

in the vicinity of Stavropol' (Georgiyevsk), at Tobol'sk, and in other regions. Other potential areas are indicated in regions 1 - 3 and 7, and possibly in certain areas of regions 4 and 5.

6. Melting of permafrost. The hot springs suitable for use in mining operations in the north (melting of permafrost) are listed as occurring in Chutkotka, the deep Cenozoic and Mesozoic troughs and basins in the Yano-Kolyma, Chukotka and Koryak folded regions and in the Yano-Sugay, Olyutor and Parapol'sko-Penzhinsk synclinal zones.

7. Servicing of swimming pools and baths.

8. Balneology.

9. Extraction of chemical salts and elements.

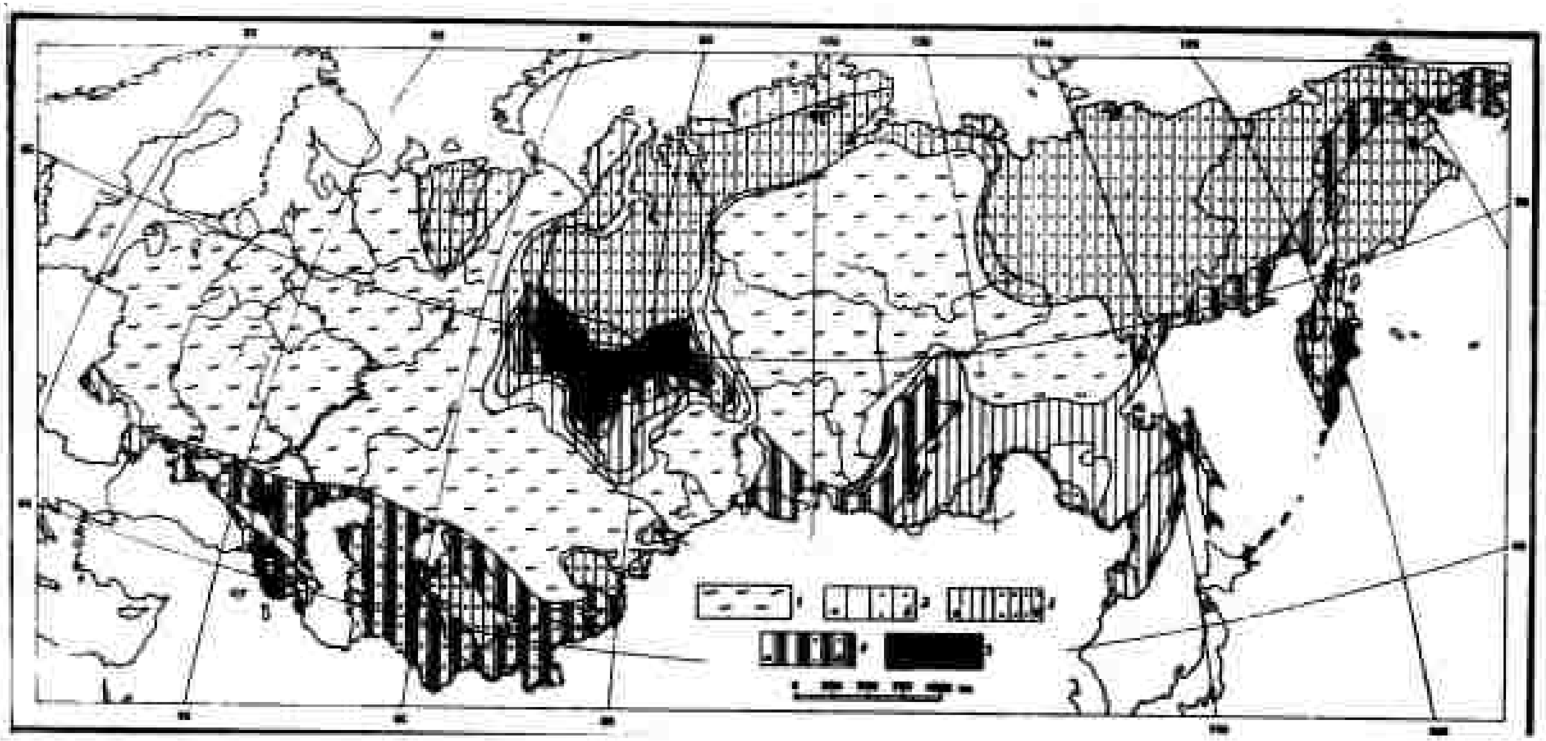


Fig. 54. Sketch Map Showing Potential Uses of Thermal Waters for Various Branches of the Economy (as per requirements cited in Table 36) (p. 210).

1 - regions where the use of thermal waters for modern technology is not economically favorable (in individual sections, the thermal waters can be extracted incidentally when deep drilling for petroleum); 2a - regions of possible utilization of thermal waters for thermal irrigation, warming the ground, melting permafrost, and for heating swimming pools and bath facilities; 2b - the same, excluding the first type of utilization; 3a - regions where all of the above enumerated uses of thermal waters are possible, in addition to their use as hot-water supply and in greenhousing-hothousing; 3b - the last two types of uses, possible only by using heat-exchangers; 4a - regions where, in addition to the above enumerated uses, space heating of population centers, cooling, and generation of electric power at geothermal electric power stations using intermediate low-boiling point substances, are possible; 4b - the same, using heat exchangers; 5a - regions in which all kinds of uses of thermal waters are possible, including a geothermal electric power station with a direct steam-water cycle; 5b - the same, using heat exchangers.

Section B.

Table 26. Results of Determinations of Heat Flow in the Russian Platform Area. (pp. 130-133).

(Gives names, numbers, coordinates, depths investigated, time lapse (in months) between drilling and temperature measurements, altitude of borehole heads, heat flow measurements (in $\mu cal/cm^2$ sec), accuracy, depth of basement, depth of Moho, and amplitudes of recent tectonic movements for 72 boreholes in the northern part of the Volga-Ural anteclise and Moscow syneclise, the Tatar arch, Rumanian uplift, the Sokso-Sheshim, Zhigulev, and Don-Medveditskiye dislocations, the Caspian foreland syneclise, the foreland Ural boundary downways, the Voronezh anteclise, and the Greater Donbass downwarp.)

Table 27. Heat Conductivity of Rocks of Various Lithological and Stratigraphic Complexes in the Caucasus Foreland Area. (p. 141).

Table 28. Results of Heat Flow Determinations in the Caucacus Foreland Area. (pp. 143-146).

Table 29. Statistics of the Heat Flow in Various Tectonic Structures of the Caucasus and Caucasus Foreland. (p. 149).

Fig. 41. Map of the Heat Flow in the Caucasus Region. (p. 151).

Table 34. Average Magnitudes of the Heat Flow in Various Tectonic Structures in the USSR and Adjacent Countries. (pp. 168-169).

Fig. 47. Sketch Map of the Geoisotherms of the Pauzhetka Pool. (p. 186).

Fig. 51. Hydrogeological Section Across the Pauzhetka Pool. (p. 193).

PROBLEMS OF DEEP-SEATED HEAT FLOW

Akademiya nauk SSSR. Institut fiziki Zemli. Problemy glubinnogo teplovógo potoka (Problems of deep-seated heat flow). Moscow, Izd-vo Nauka, 1966, 145 p.

This collection of articles represents one of the major pre-1968 references on the goethermy of the USSR. In the table of contents below, all but two of the articles are accompanied by annotations reflecting the general content or specific items of interest appearing in the article.

Table of Contents

4. Kutasov, I. M., Ye. A. Lyubimova, and F. V. Firsov. Recovery rate of temperature field in boreholes on the Kola Peninsula. 74-87

(Discusses methods used and gives results. Bibliography cites 4 Soviet and 5 non-Soviet references).

5. Lyubimova, Ye. A., and F. V. Firsov. Determination of heat flow in some regions of Central Asia. 88-106

(Contains a small-scale sketch map showing sites of investigations in the Kazakhstan area between Alma-Ata on the south, to Frunze on the west, Taldy-Kurgan on the east and north to Lake Balkhash and Karaganda on the north. The data presented include the types of rocks in which the measurements were made, water temperatures and the geothermal gradients, heat conductivity, and heat flow measurements. The bibliography cites 4 Soviet and 2 non-Soviet references).

6. Lyubimova, Ye. A., V. A. Shelyagin, and A. P. Shushpanov. Apparatus used to determine deep-seated heat flow. 1-7-132

(The bibliography cites 9 Soviet and 4 non-Soviet references).

7. Shushpanov, A. P. On the heat regime of the Carpathian area of the USSR. 133-143

(Presents borehole data obtained in both the Hungarian and Ukrainian areas of the Carpathians: borehole depths and temperatures, the stratigraphy and lithology of the formation involved, the temperature gradients, and the heat conductivity. The bibliography cites 6 Soviet and 7 non-Soviet references). 133-143

GEOTHERMAL INVESTIGATIONS

Akademiya nauk SSSR. Institut fiziki Zemli. Geotermicheskiye issledovaniya (Geothermal investigations). Moscow, Izd-vo Nauka, 1964, 176 p.

In this book, another major pre-1968 reference, edited by Ye. A. Lyubimova, three major topics are discussed as outlined below.

1. Principles of Determination of Heat Flow from the Earth's Interior and Measurement Results (pp. 5-102), written by Ye. A. Lyubimova, L. N. Lyusova and F. V. Firsov, deals with the importance of heat flow data in understanding the physics of the earth, factors causing the deviation of borehole temperatures from actual rock temperatures, and problems involving field methods and equipment (the last discussion includes relatively detailed drawings of the T-8 and T-9 resistance thermometers). Other parts of this section of the book describe the results of measurements of deep-seated temperatures (borehole temperatures and geological sections) in the Ukraine, the Belgorod area, and the Stavropol' and Krasnodarskiy krays, as well as heat flow investigations. This section of the book contains a list of 37 Soviet and 34 non-Soviet references.

2. Analysis of Errors in Electrical Circuits Used in Measuring Temperatures in Deep Boreholes, written by A. P. Shushpanov (pp. 105-114). The bibliography contains 10 Soviet and 3 non-Soviet references.

3. Thermophysical Investigations of Rocks, written by Ye. A. Lyubimova, G. N. Starikova, and A. P. Shushpanov (pp. 115-174). The bibliography contains 30 Soviet and 10 non-Soviet references.

PART II. INFORMATION ON THE GEOTHERMY OF SPECIFIC AREAS OF THE USSR

HYDROCHEMICAL ANOMALY OF THE UZON HEAT FIELD ON KAMCHATKA

Pilipenko, G. F. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka, Moscow, 1971, 229-238.

Contains tables giving the comparative characteristic chemical compositions of the Uzon area hot springs by hydrochemical zones and the chemical characteristics of some of the hot springs in the Uzon caldera, as well as the following two sketch maps:

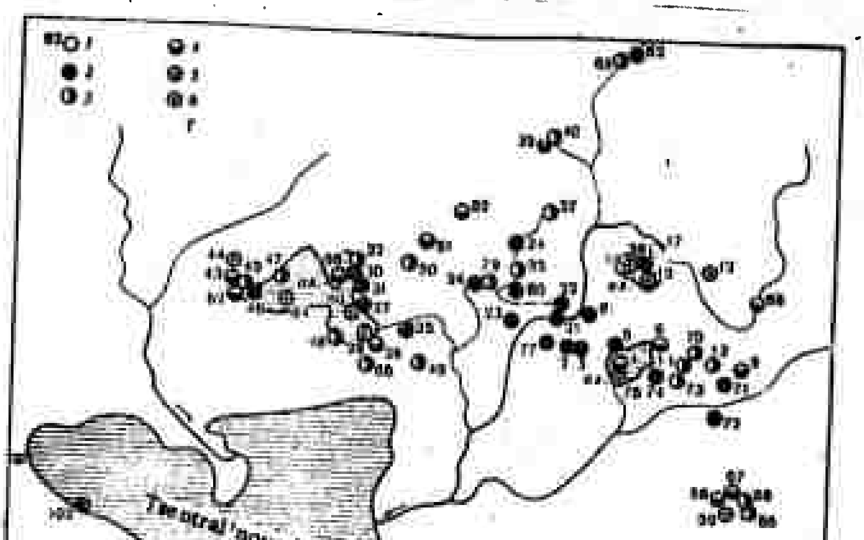


Fig. 1. Sketch Showing the Locations of the Uzon Hot Springs.

1 - hot spring numbers; 2-6 - hot springs with temperatures: 2 - higher than 70°C, 3 - 50-70°C, 4 - 30-50°C, 5 - 15-30°C, 6 - lower than 15°C.

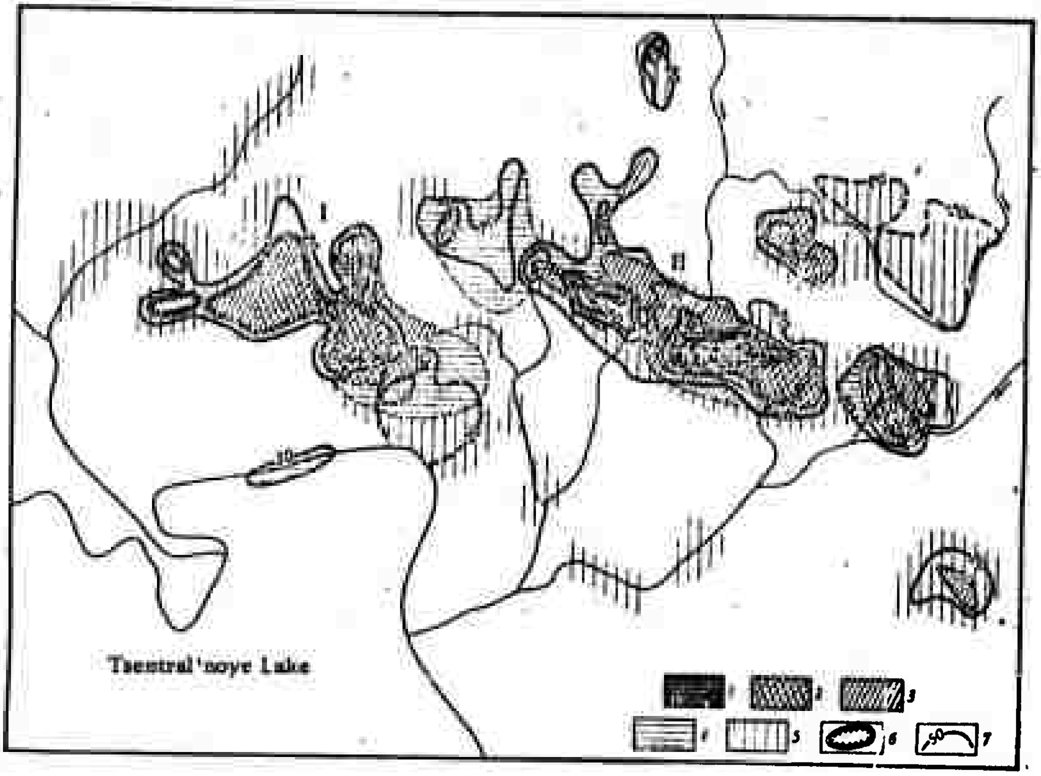


Fig. 2. Sketch Showing the Hydrochemical Zonality of Discharge Sites of the Uzon Steam-Boiling Springs (status in July - September 1966/1967).

The discharge zones are: 1 - sodium chloride waters; 2 - sodium sulfate - sodium chloride waters; 3 - sodium chloride - sodium sulfate waters; 4 - sodium hydrocarbonate - chloride and sodium chloride - hydrocarbonate waters; 5 - sulfate, hydrocarbonate - sulfate, and sulfate - hydrocarbonate waters of complex cation composition; 6 - acidic hot water lake (pH 2-3); 7 - isolines of temperature (T^{o}) measured at depth of 0.5 m; I - thermal sector of Fumarol'noye Lake; II - Eastern heat field.

HOT SPRINGS OF THE KIREUNA VALLEY IN THE CENTRAL RANGE OF KAMCHATKA

Kirsanova, T. P. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka, Moscow, 1971, 239-246.

Describes the geography, structural geology and lithology of three hot spring areas in the Kireuna river valley: the upper group, the middle group and the lower group. The following large-scale sketch maps are given in the text:

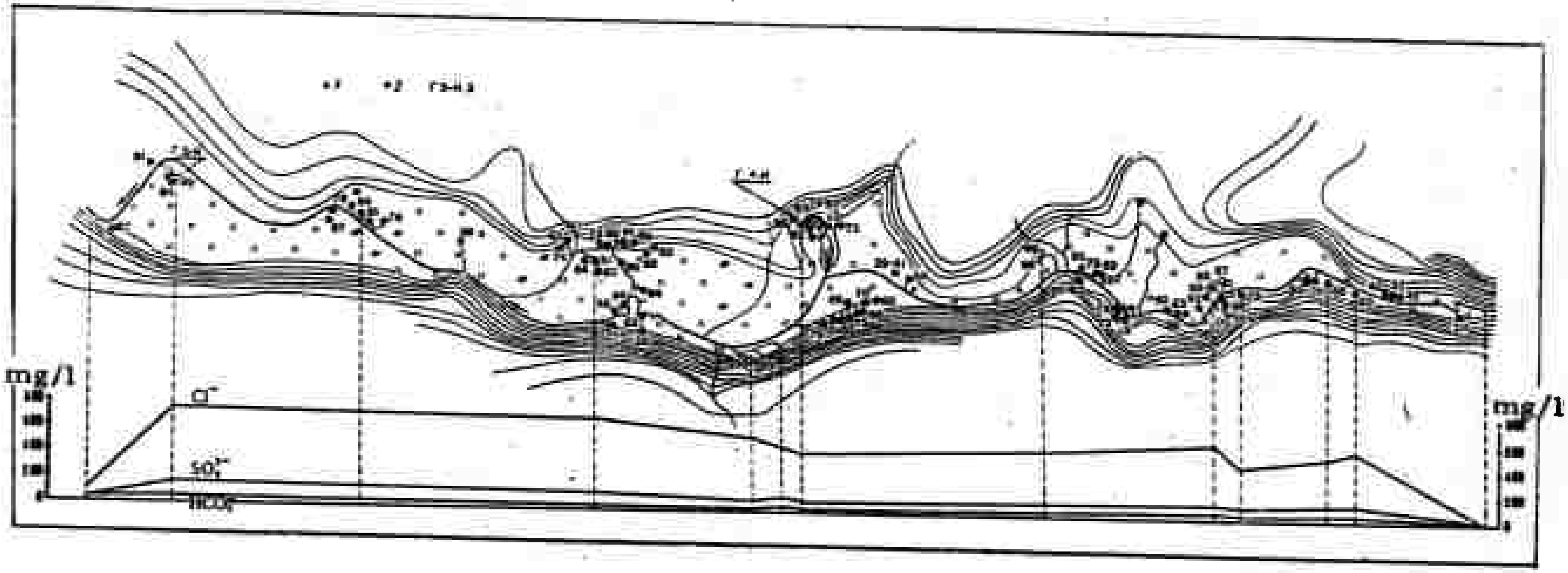


Fig. 1. Schematic Map Showing Vent Sites of Hot Springs in the Upper Group (about 100 springs, maximum temperature of 98.5 to 99°C, estimated heat capacity of 5000 kcal/sec).

1 - boiling springs; 2 - springs having water temperatures below 98°C; and 3 - sites at which gas samples were taken. A graph at the bottom of the map shows the Cl^-, SO_4^{2-} and HCO_3^- contents in the samples in mg/l.

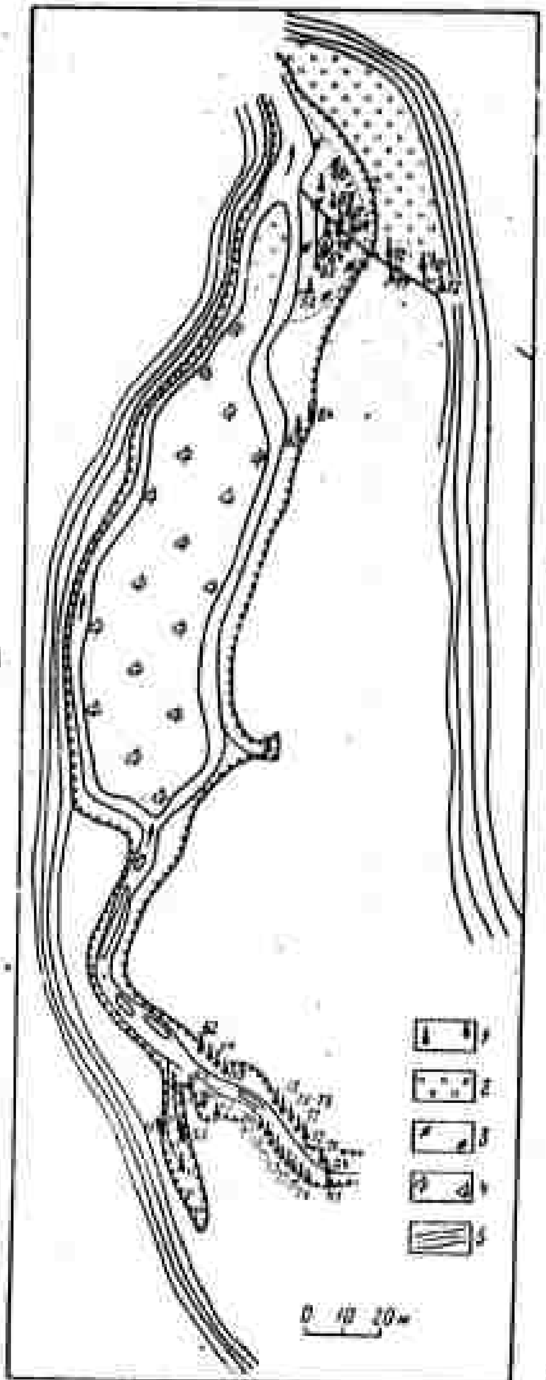


Fig. 2. Middle Group of Hot Springs (t = 77°C).

1 - Springs and their temperatures; 2 - warm-water swamp; 3 - rocky hot spring area; 4 - forested areas within the hot spring groupings; 5 - (approximate) contours.

Reproduced from best available copy.

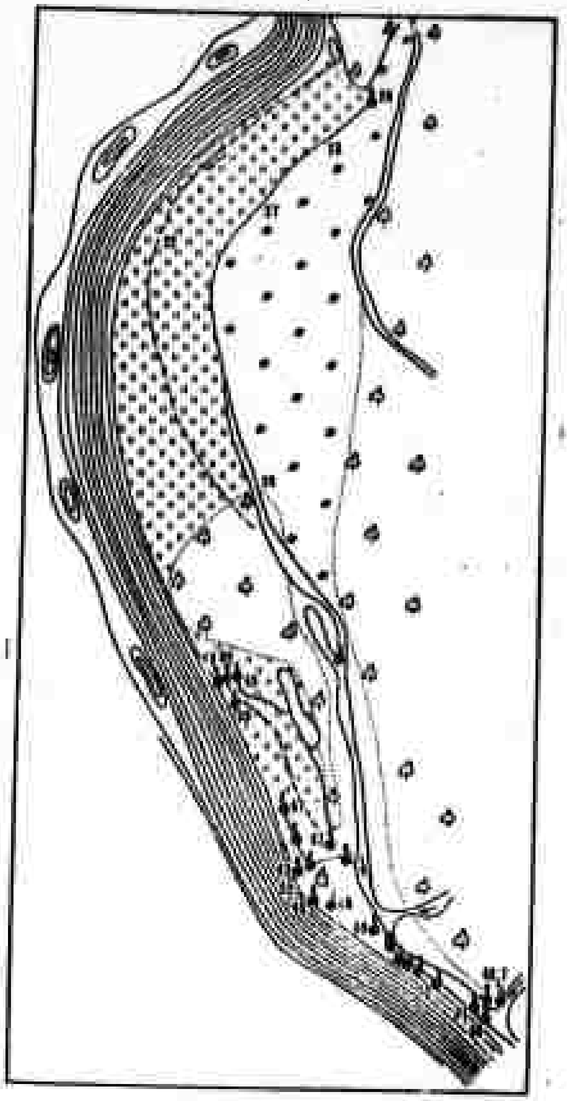


Fig. 3. Sketch Map Showing Sites of the Malyy Klyuch Hot Springs of the Lower Group (t = 67°C).

1 - Springs and their temperatures; 2 - warm-water swamp; 3 - rocky hot spring area; 4 - forested areas within the hot spring groupings; 5 - (approximate) contours.

Data on the kinds and percentages of metals determined in rock and water samples and the compositions of the hot-springs are given in two tables.

THE BOL'SHE-BANNAYA HYDROTHERMAL SYSTEM ON KAMCHATKA

Krayevoy, Yu. A., V. A. Kovalenko, and A. D. Yevtukhov. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Moscow, Izd-vo Nauka, 1971, 246-253.

The results of investigations carried out in the 1961-1969 period on the Bol'she-Bannaya hydrothermal system in Kamchatka by the Kamchatka Territorial Geological Administration are reported. Brief statements are given on the geological and lithological characteristics of the 65 km^2 area in which the boiling springs and steam vents occur. The thermal, hydrological, and chemical characteristics of the system are summarized in the following table.

Thermal phenomena	Amt. natural discharge, l/sec	Max. temp. of natural effluents, °C	Heat capacity (natural discharge), kcal/sec	Formulas of chemical composition of water
Bol'she-Bannyye steam-hot springs	60 *	98	8 400 **	$H_2SiO_3\ 0{,}215\ M_{1,2}\ \frac{SO^4\ 68\ Cl'\ 23}{(Na+K)\ 91}$ pH 8,4
Malyye Bannyye hot springs	1,5	78	117	$H_2SiO_3\ 0{,}116\ M_{0,8}\ \frac{SO^4\ 62\ HCO^3\ 20\ C\ 118}{(Na+K)\ 83\ Ca\ 15}$ pH 8,0
Karymchinskiye hot springs	100 *	94	11 000***	$H_2SiO_3\ 0{,}208\ M_{0,9}\ \frac{SO^4\ 54\ HCO^3\ 25\ Cl\ 21}{(Na+K)\ 90}$ pH 8,1

*Taking into account latent dischargeat drain-off level
**Taking into account heat content of the steam-water mix of boiling springs
***Heat loss due to heat conductivity of rocks taken into account. Data of V. G. Okhapkin

Table 1. Characteristics of Natural Thermal Phenomena in the Bol'she-Bannaya Hydrothermal System.

The geological and geothermal data are summarized in a schematic map and in two hydrogeological sections constructed from borehole data (see Figs. 1 and 2).

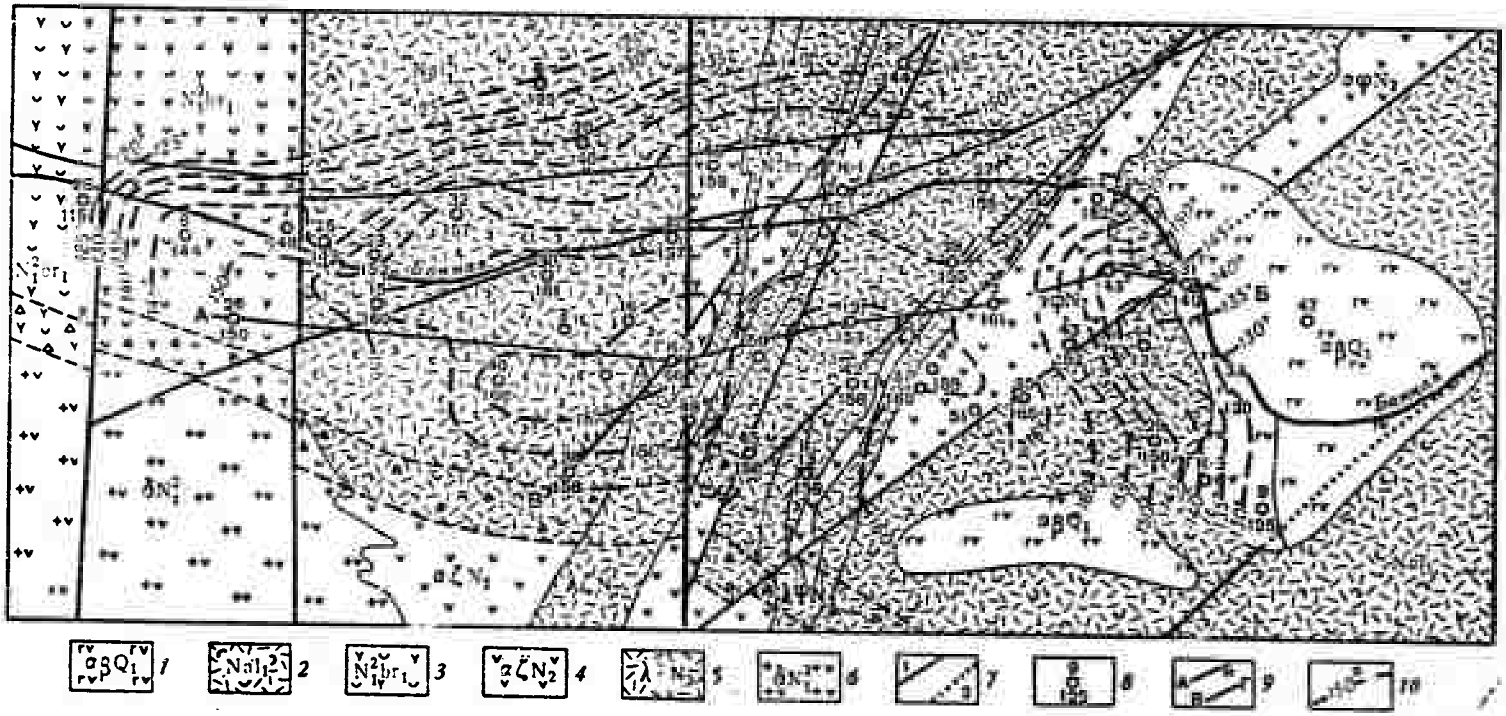
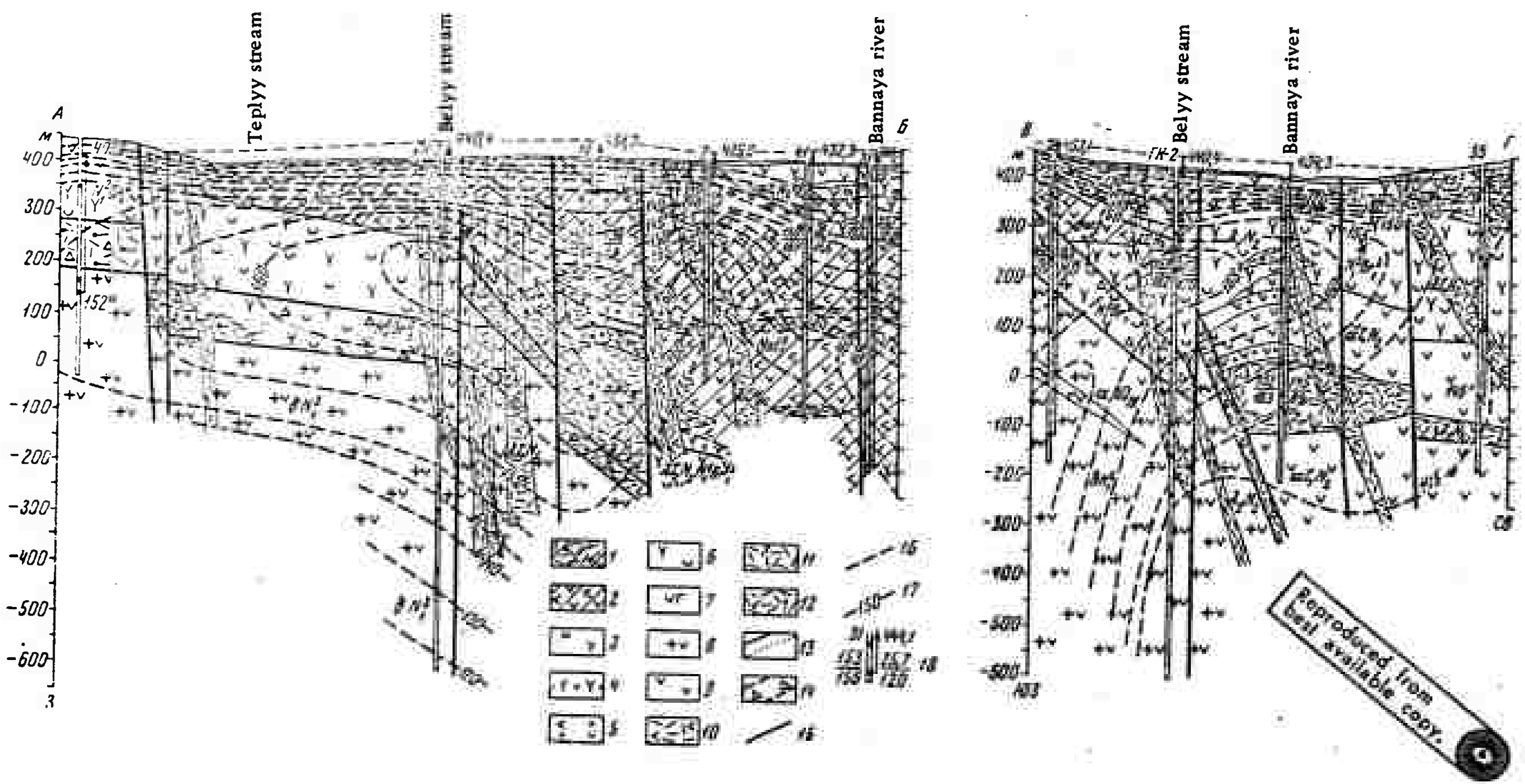


Fig. 1. Schematic geological-geothermal map of the Bol'she-Bannaya superheated hot-spring pools.

1 - andesite-basalts; 2 - andesites, andesite-dacites and their tuffs, welded rhyolite tuffs, tuffaceous conglomerate; 3 - andesite tuffs, ignimbrites; 4 - sub-volcanic andesite-dacite bodies; 5 - rhyolite-dacites; 6 - diorites and granodiorites; 7 - tectonic dislocations, determined (1) and passing under Quaternary deposits (2); 8 - borehole, upper (number) and lower (temperature) at the absolute level of 200 m; 9 - hydrothermal cross section profile line; 10 - geoisotherms.



Reproduced from best available copy.

Fig. 2. Hydrogeological sections determined from borehole measurements.
1 - welded tuff rhyolite flows; 2 - andesite-dacite and andesite lavas; 3 - tuffaceous conglomerates of mixed composition; 4 - tuffs of mixed composition; 5 - andesite-dacite and andesite tuffs; 6 - andesite-dacite and dacite ignimbrites; 7 - andesite-basalts; 8 - quartz diorites, granodiorites, granosyenites; 9 - andesites and andesite-dacites; 10 - rhyolite-dacites; 11 - rhyolites; 12 - welded rhyolite tuffs; 13 - tectonic dislocations; 14 - brecciated zones; 15 - geological contacts, determined; 16 - geological contacts, inferred; 17 - geoisotherms; 18 - boreholes: top numbers represent borehole number and absolute level of the piezometer, lower left number represents heat content: numerator, for one sampling, denominator - under reaction conditions; numbers on right are corresponding borehole discharges.

On the basis of preliminary field investigations and calculations, the thermal capacity of these steam - and hot springs is estimated as 75,000 kcal/sec and that of the specific heat flow density for the 50 km^2 area as about 1500 kcal/sec km^2, i.e., they are comparable with the specific heat loss at Pauzhetka and other such systems on Kamchatka and outside the Soviet Union.

THE PARATUNKA HOT-SPRING SYSTEM IN KAMCHATKA.

Manukhin, Yu. F., V. I. Vorob'yev, L. A. Vorozheykina, K. I. Mal'tseva, S. I. Fedorenko. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka, Moscow, 1971, 253-261.

The Paratunka (Kamchatka) hydrothermal system extends for more than 30 km along the Paratunka River valley and consists of seven groups of hot springs (temperatures up to 100°C). The chemical and hydrological characteristics of these hot-spring systems are summarized in the tables that follow:

Groups of springs	Observed discharge, l/sec	Discharge taking into account latent discharge in water, l/sec	Max. temp. of water, °C	Heat capacity, kcal/sec	Chemical composition formula
Severnyye (Northern)	0,3	—	3,0	—	$M_{0,9}\frac{SO_4 81 Cl 15}{(Na+K)51 Ca 46}$
Nizhniye (Lower)	26,3	—	61,6	1619	$M_{1,3}\frac{SO_4 71 Cl 24}{(Na+K)64 Ca 38}$
Sredniye (Middle)	—	3,5	81,5	300	$M_{1,1}\frac{SO_4 84 Cl 13}{(Na+K)66 Ca 32}$
Verkhniye (Upper)	15,0	70,0	70,2	4914	$M_{1,0}\frac{SO_4 49 Cl 43}{(Na+K)51 Ca 49}$
Karymshinskiye		130,0	76,5	9945	$M_{0,65}\frac{SO_4 87}{(Na+K)86 Ca 11}$
Sivkiny	—	47,0	18,5	870	$M_{0,5}\frac{SO_4 66 Cl 21}{(Na+K)90 Ca 10}$
Ovrazh'yi	—	8,0	16,0	128	$M_{0,35}\frac{HCO_3 48 SO_4 34 Cl 18}{Ca 50 (Na+K)45}$
Total		258,5		17 776	

Table 1. Characteristics of the Surface Hot Springs of the Paratunka System.

Sector, borehole	Hardness, overall, mg-equiv/1	Dry residue, mg/1	Mineralization, mg/l	pH / Eh, mv	Anions SO_4^{2-}	Cl^-	HCO_3^-	CO_3^{2-}
Middle Paratun. sector, GK-2	5,93	1260	1243,49	9,0 / +60	710,25	72,42	10,37	13,80
Lower Paratun., 45	9,52	1971	1922,06	6,50 / +90	813,12	368,13	37,21	not detected
Northern, GK-9	15,16	206,90	2009,6	8,3	1147,26	161,88	18,30	3,00
Karymshinskiy, GK-5	2,52	972,00	996,01	8,2	446,07	131,35	43,92	1,50
Springs (72°)	2,35	—	509,67	7,5	144,00	119,21	43,52	not detected
Upper-Paratun., spring (70°)	2,60	—	997,00	8,5	500,0	111,00	26,00	not detected

Sector, borehole	Cations Na^+	K^+	Ca^{2+}	CO_2	Al	NH_4	SiO_2
				mg/1			
Middle-Paratun. sector, GK-2	245,19	7,98	118,60	not detected	0,30	0,25	65,0
Lower Paratun., 45	405,32	9,98	190,4	5,81	0,12	0,10	92,0
Northern, GK-9	305,45	8,38	303,20	not detected	0,08	0,20	59,0
Karymshinskiy, GK-5	254,06	5,11	50,40	not detected	0,40	0,2	42,0
Springs (72°)	108,75		46,99	7,92	—	0,2	47,0
Upper Paratun., spring (70°)	261,0		53,00	—	1	not detected	45,0

Table 2. Chemical Composition of the Hot Springs of the Paratunka Pools, mg/l.

The hydrogeological data are summarized on a large-scale map (Fig. 1) and in three sections (Fig. 2).

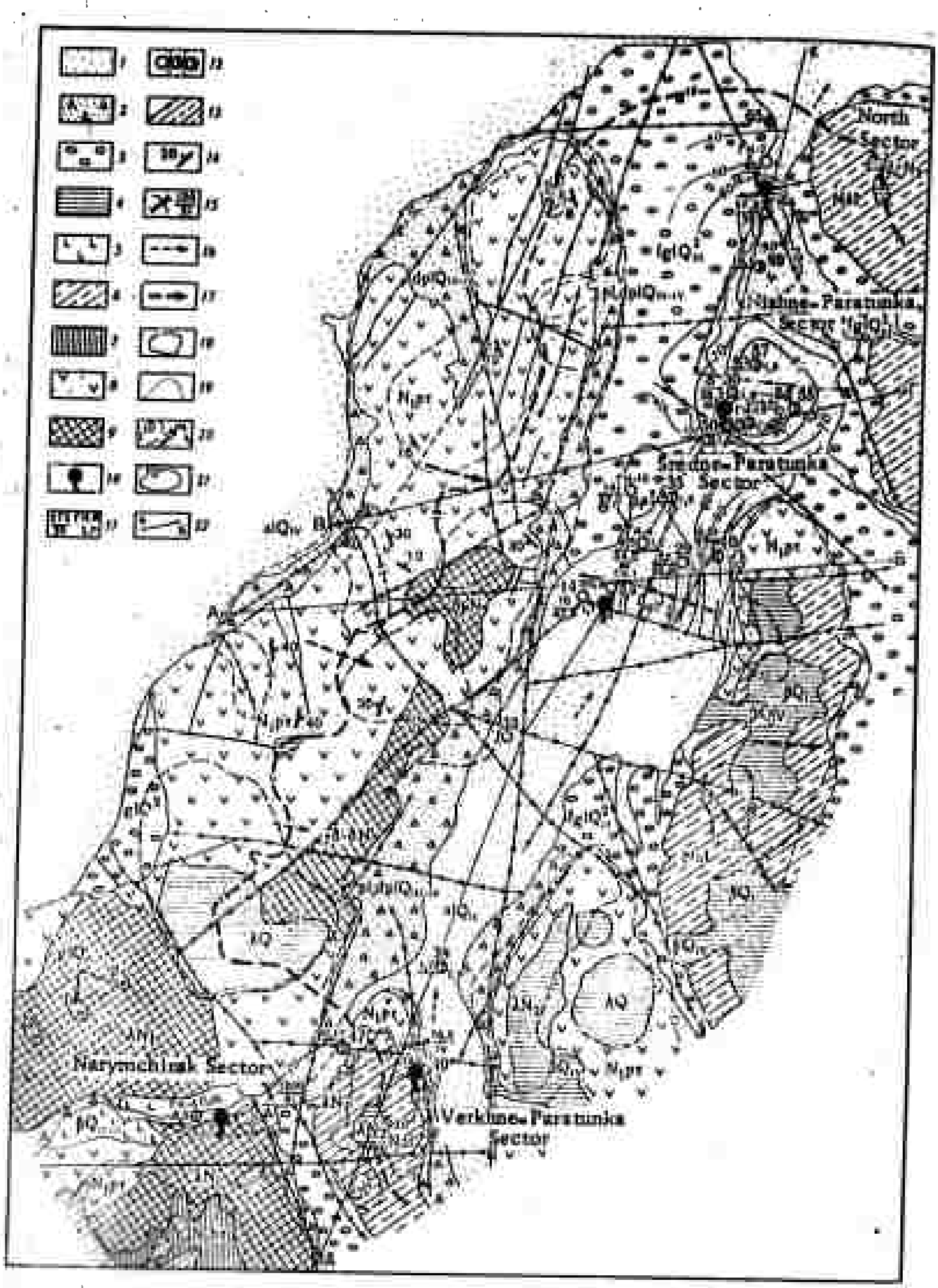
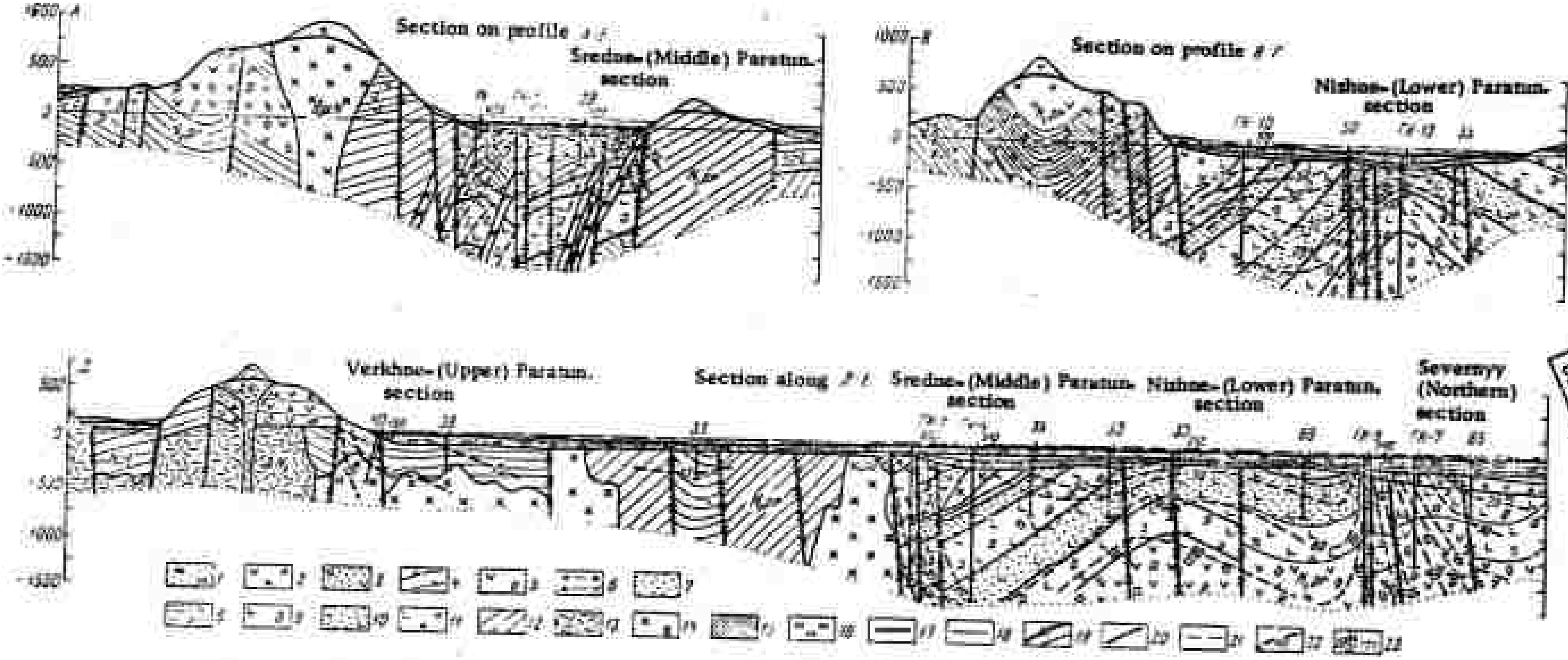


Fig. 1. Schematic Hydrogeological Map of the Paratunka Hot Spring Pools (see legend* on next page).

*) Due to a great number of inconsistencies in the original legend to this map, the translated legend has been revised to correspond to the map symbols.

1 - water-bearing bed of Recent alluvial deposits alQ_{IX} (sandy-gravelly -pebbly deposits containing boulders, occasionally-sandy loam); 2 - water-bearing complex of Recent and Upper Quaternary alluvial and talusalluvial fan deposits pl, $dplQ_{III-IV}$ (gravelly-pebbly and psephitic -detrital deposits containing sand and sandy loam matrixes); 3 - water -bearing complex of Recent and Upper Quaternary glacial and fluvio-glacial deposits dl, $fglQ^{2}_{III}$, glQ_{IV} (gravels, sands, boulder-pebble deposits containing sand and sandy loam matrixes; 4 - water-bearing bed of Quaternary and Neogene extrusives and volcanic structures - βQ_{IV}, βQ_{I}, λQ_{I}, λN_2, $d\beta N_2$, λN (rhyolites, basalts, andesite -basalts and their scoria, andesite-dacites); 5 - water-bearing bed of the Middle - Upper Quaternary lava flows and acidic tuffs - βQ_{II-III}, λQ_{II-III} (basalts, rhyolite tuffs); 6 - water-bearing complex of Upper Miocene-Pliocene volcanic formations of the Alneyian series - Nal (basalts, andesite and rhyolite tuffs, ingimbrites); 7 - water-bearing complex of the Middle Miocene effusive-pyroclastic and welded tuff - sedimentary formation of the Berezovian series - $N_1b\tau$ (tuffs and rhyolite tuffites, rhyolites); 8 - water-bearing complex of Miocene effusive-tuffaceous-sedimentary formations of the Paratunian series $N_1p\tau$ (andesite tuffs, andesite-dacites, basalts, andesite-basalts, andesite, andesite-dacite and andesite-basalt flows); 9 - water-bearing complex of Miocene intrusives and the rocks of subvolcanic bodies (granodiorites, diorites, quartz diorites, diorite porphyries, rhyolites); 10 - hot springs; 11 - boreholes drilled to the hot water: top right number represents the borehole number; left (numerator) is discharge in l/sec; left (denominator) is static level at absolute level; lower right is the mineralization in g/l; 12 - waters: ○ - containing predominantly the sulfate ion; ◐ - chloride - sulfate; ◑ - chloride - hydrocarbonate; ● - mixed type; 13 - faults: a - water-bearing (-×-×-×-), b - determined (——) and postulated (- - - -) whose hydrogeological values were not indicated; 14 - elements of rock deposition; 15 - site at which the total discharge of the hot spring was measured, where the Arabic number is the yield in l/sec and the Roman numeral is the date (month) of the measurement; 16 - general direction of movement of hot-spring water in the upper parts of the pre-Quaternary section; 17 - assumed direction of movement of deep-seated sub-surface flow; 18 - boundaries between water-bearing beds and complexes; 19 - contacts between rocks of different age and the boundaries of one water-bearing bed or complex; 20 - isolines of minimum subsurface flow: a (light lines) - within the boundaries of local sectors, and b (dark lines) - within the limits of aquifer areas (the numeral indicates the modulus in $l/sec \cdot km^2$); 21 - geoisotherms at the 600-m depth, in ^{o}C; 22 - hydrogeological section line.



Reproduced from best available copy.

Fig. 2. Schematic Hydrogeological Sections (Profiles for Sections in Fig. 1).

1 - sandy-gravelly-pebbly deposits; 2 - psephitic rhyolite tuffs; 3 - rhyolite tuffs, psammitic (arenaceous); 4 - ignimbrites and ignimbrite-like tuffs; 5 - andesite and dacite tuffs, psephitic, containing andesite and dacite flows; 6 - interbedded tuffs of average composition, psammitic and psephitic, containing andesite and dacite flows; 7 - average-composition psammitic tuffs; 8 - average-composition silty-pelitic and psammitic tuffs containing andesite flows; 9 - psephitic basalt tuffs, containing basalt flows; 10 - interbedded, silty-pelitic, psammitic and small-ejecta psephitic basalt tuffs, containing basalt flows; 11 - psephitic andesite and basalt tuffs; 12 - interbedded volcanic and sedimentary rocks, primarily tuffs of varying composition; 13 - rhyolites; 14 - intrusives (diorites, quartz diorites, granodiorites, diorite-porphyries); 15 - argillites and siltstones (assumed to be relatively impermeable); 16 - conglomerates; 17 - contacts between rocks of various ages; 18 - contacts between lithologically different rocks of a single age; 19 - faults: a - water-bearing (dark line) and b - hydrogeological importance not determined (light line); 20 - water table at free surface; 21 - piezometric level; 22 - geoisotherms; 23 - boreholes: top (larger) number is the borehole number on the map; the arrow is ground-water head; and the number (smaller) near the arrow is absolute elevation of the piezometric water level.

HOT WATERS OF THE ALBIAN AQUIFEROUS COMPLEX OF THE YUZHNO-MANGYSHLAK DEPRESSION

Vasil'yeva, I. L. and N. S. Otman. Sovetskaya geologiya, no. 2, 1969, 153-156.

The hot water aquiferous beds of Albian age, located in the Yuzhno-Mangyshlak depression near the southwestern coast of the Caspian Sea in Kazakhstan, are identified as being the most promising in the area for

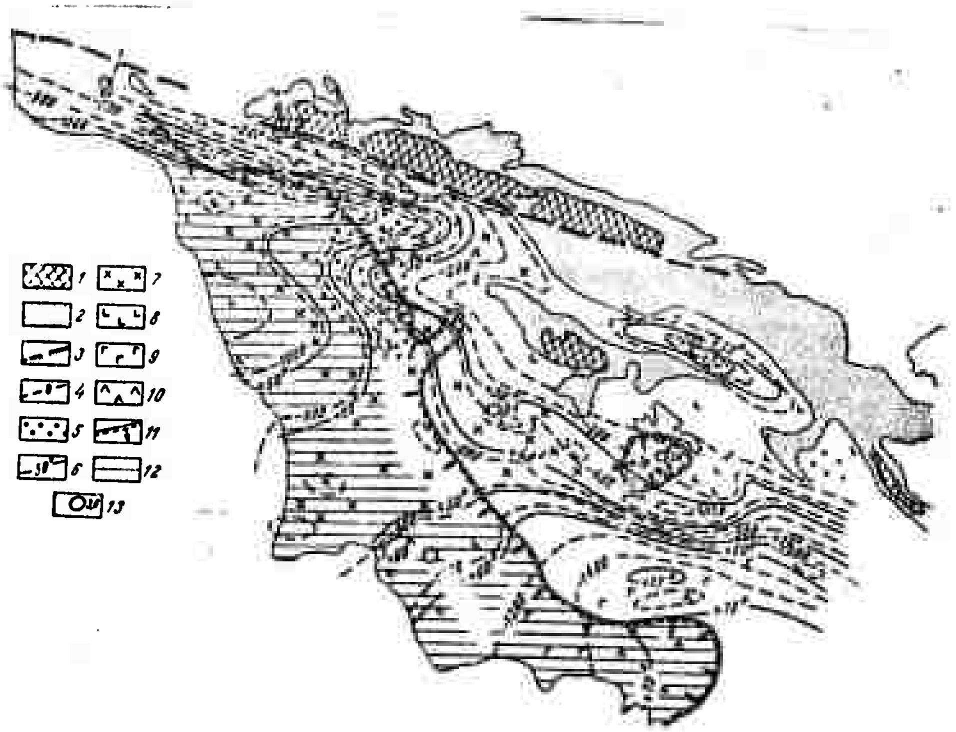


Fig. 1. Hydrogeothermal Map of the Albian Aquiferous Complex of the Yuzhno-Mangyshlak Depression.

1 - areas in which Lower Cretaceous deposits are missing; 2 - areas in which Lower Cretaceous deposits outcrop on the surface; 3 - faults; 4 - structural contours of the top of the Lower Cretaceous; 5 - sectors in which ground water with overall mineralizations of up to 3 g/l occurs; 6 - isotherms along the top of the Lower Cretaceous; 7 - sectors in which ground water with overall mineralizations of from 3 to 10 g/l occurs; 8 - the same, with mineralization ranging from 10 to 35 g/l; 9 - the same, with mineralization ranging from 35 to 50 g/l; 10 - the same, with mineralization exceeding 50 g/l; 11 - boundary of zones of self-discharge ground water from the Albian aquiferous complex; 12 - areas in which hot water having temperatures of more than +40°C occurs; 13 - magnitude of geothermal gradient.

such purposes as power and water supply for industrial uses on the peninsula. The author has compiled a hydrothermal map (see above) which shows water temperatures registered along the top of the Albian aquiferous complex, variations in the overall mineralization of the water throughout the depression, and the geothermal gradients. He has also identified areas where the water is discharged and where water temperatures are higher than +40°C.

Area	Depth of occurrence, m		Water temp., 0° C		Average [illegible], °C/100m	Comments
	at top	at base	at top	at base		
Zhetybay	530—570	1080—1175	34—38	54—57	3,3	
Uzen'	211—440	800—1045	22—30	42—50	3,6	
Karamandybas	346	932	30 (at 500m depth)	46	3,7	
Tenga	516—589	1155—1242	35—40	60—64	3,6	
Karagiye	912	1441	59	78	3,6	
Senek	—	—	—	—	3,4	Gradient determined for the upper part of the bed
Tyuesu	—	—	—	—	3,6	Gradient determined for the upper part of the bed

Shown in the table above are the values representing the geothermal gradient of the Albian aquiferous complex.

VOLCANISM AND THE HOT SPRINGS OF THE UZON-SEMYACHIKSKAYA GEOTHERMAL REGION OF KAMCHATKA

Aver'yev, V. V., G. Ye. Bogoyavlenskaya, O. A. Braytseva, Ye. A. Vakin, G. F. Pilipenko. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka Moscow, 1971, 207-211.

Contains two tables summarizing the thermal and chemical characteristics of the Uzon-Geyzernaya and Semyachikskaya hydrothermal systems located in the eastern volcanic zone of Kamchatka.

System	Max. temp. natural vents, °C	Predicted heat capacity, kcal/kg	Natural heat capacity, 10^3 kcal/sec	Area of heat supply*, km²	Intensity of heat supply, μcal/sec·cm²	Investigators, years studied
Uzon-Geyzernaya			134	120	110	
Uzon caldera	Boiling	250	64			Aver'yev, Kovalev, Slezin, Pilipenko, (1966-1967)
Valley of Geysers	Ditto	>250	70			Aver'yev (1962)
Semyachikskaya			75	100	75	Aver'yev, Vakin, Kovalev. (1965)
Verkhne-Semyachikskiy sector	137	~640 (steam)	50			
Nizhne-Semyachikskiy sector	50	100	25			

*Ring-structure area

Table 1. Heat Parameters of the Uzon-Geyzernaya and Semyachikskaya Hydrothermal Systems.

System			Ascension springs	Peripheral springs	Fumarole-hot springs (Undrained pools)	Condensates of steam vents
Uzon-Geyzernaya	Uzon caldera	Typical sample	Geyzerite hot springs	Posledniy springs	Western field	Eastern field
		Mineralization, g/l	2,1	1,2	3,0	0,05
		Chem. composition formula	$\frac{Cl94}{Na90K5}$	$\frac{SO_4 75 HCO_3 20}{Mg53 (Na+K) 38}$	$\frac{(HSO_4+SO_4) 100}{Al39H37Fe22}$	$\frac{HCO_3 100}{NH_4 100}$
		t, °C	84	55	96	95
		pH	8	7	2,1	8
	Valley of Geysers	Typical sample	Velikan geyser	Nizh. (Lower) Geyser sector	Verkh. (Upper) Geyser sector	—
		Mineralization, g/l	1,8	0,6	1,2	—
		Chem. composition formula	$\frac{Cl85SO_4 10}{Na95}$	$\frac{SO_4 86 HCO_3 14}{Na48Ca43}$	$\frac{SO_4 97}{(Na+K) 69Mg12H8}$	—
		t, °C	Boiling	68	98	—
		pH	7.6	7.2	3.5	—
Semyachikskaya		Typical sample	Nizhne-(Lower) Semyachikskaya spring	Inter-montane basin	Sulphate field of Burlyashiy volcano	Central Semyachik volcano
		Mineralization, g/l	1,7	2,1	0,9	[illegible]
		Chem. composition formula	$\frac{Cl59HCO_3 28SO_4 13}{Ca59Mg28Na21}$	$\frac{SO_4 67HCO_3 28}{Ca61Mg31}$	$\frac{SO_4 94}{Na36NH_4 33Al_2O}$	[illegible]
		t, °C	49	55	95	[illegible]
		pH	6,5	7,5	2,3	[illegible]

Reproduced from best available copy.

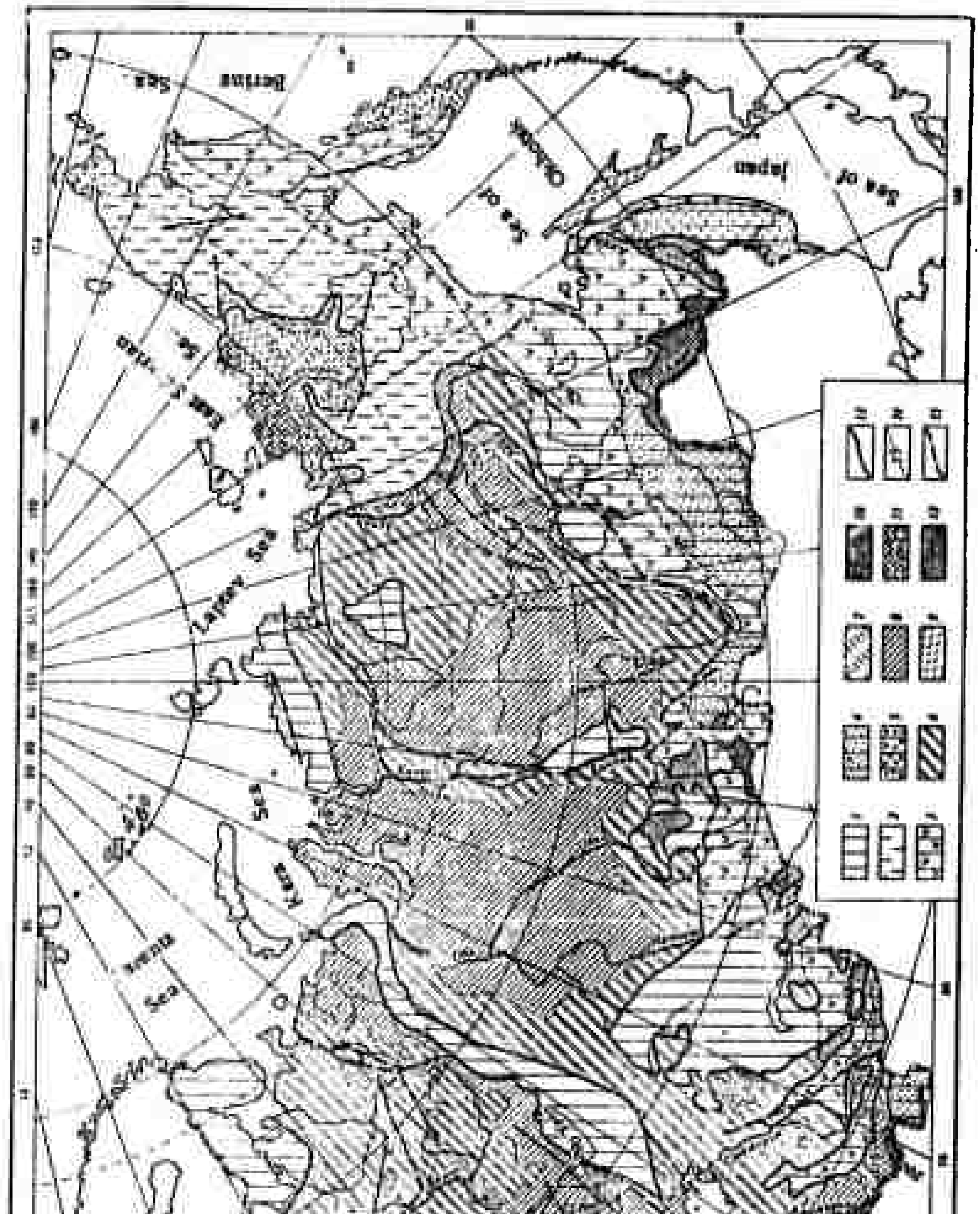
Table. 2. Comparative characteristics of the Chemical Composition of the Steam-Hot Springs.

GASES OF THE SUBSURFACE HYDROSPHERE OF THE USSR

Shcherbakov, A. V., F. A. Makarenko, G. N. Smirnova. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Podzemnyye vody Sibiri i Dal'nego Vostoka (The ground water of Siberia and the Soviet Far East). Izd-vo Nauka, Moscow, 1971, 22-28.

Using all information available in 1968, the authors began a study of the regional patterns and interrelationships of the ground water and gases contained in the earth's crust in USSR territory, first investigating the gas compositions and saturations of the ground water and then determining and mapping the overall occurrence of gases and the distribution of individual gases in terms of their genetic associations. The paper briefly summarizes the procedures used and the general results obtained in the study and presents the small-scale map reproduced below.

(continued with map on next page)


Black Sea
Caspian Sea
Baltic Sea
Barents Sea
Kara Sea
Laptev Sea
Sea of Japan
Bering Sea

Sketch Map Showing the Distribution of Gases and Ground Water in the USSR Territory

I - areas of occurrence of deep-seated oxidation conditions with local occurrences of ascending gaseous-hydrothermal manifestations: 1 - cold-water zones ($t < 20^{\circ}C$) of varying ion content containing gases of atmospheric origin (O_2, N_2, CO_2, etc.); 2 - the same, postulated; 3 - zone of ascending nitrogen hot springs; 4 - zone of ascending carbonic acid water (cold and hot); 5 - zone of volcanic steam vents and hot springs. II - areas of replenishment in the lower part of the sedimentary regolith; 6 - zones of chloride water having temperatures up to $75^{\circ}C$, frequently enriched with biochemical gases (N_2, CO_2, H_2S, CH_4, etc); 7 - the same, postulated; 8 - zone of chloride water with temperatures from 75° to 200° containing chemical and thermocatalytic gases of hydrocarbon composition (CO_2, H_2S, etc.); 9 - the same, postulated; 10 - zone of chloride water with temperatures above 200° containing thermo-metamorphic hydrocarbons of the methane series (methanization zone), CO_2, CO, H_2S, H_2, etc; 11 - the same, postulated; 12 - deep intermontane depressions and basins containing water of varying ion and gas composition; 13 - boundaries of shields, highlands and fold-mountain areas; 14 - isotherms on the surface of the crystalline and folded basements (in $^{\circ}C$); 15 - lines of major tectonic faults.

STATUS AND POTENTIALS OF LONG-RANGE HYDROGEOLOGICAL INVESTIGATIONS IN SIBERIA AND THE SOVIET FAR EAST

Pokryshevskiy, O. I. and V. A. Korobeynikov. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Podzemnyye vody Sibiri i Dal'nego Vostoka (The ground water of Siberia and the Soviet Far East). Izd-vo Nauka, Moscow, 1971, 3-7.

In addition to mentioning the use of the Pauzhetka (Kamchatka) thermoelectric station in providing power, discusses studies carried out in the Pitatelevskiy area (Buryat ASSR) used as source of central heating, two additional sites on Kamchatka (central heating for Petropavlovsk-Kamchatkiy) and a thermoelectric station, as well as explatory work on Kunashir Island (Kuriles).

THERMAL REGIME OF THE UPPER PART OF THE EARTH'S CRUST IN SIBERIA AND THE SOVIET FAR EAST, IN CONNECTION WITH ESTIMATES OF HYDROTHERMAL RESOURCES

Makarenko, F. A., G. B. Gavlina, B. G. Polyak, and Ya. B. Smirnov. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Podzemnyye vody Sibiri i Dal'nego Vostoka (The ground water of Siberia and the Soviet Far East). Izd-vo Nauka, Moscow, 1971, p. 44-48.

Includes two small-scale maps: 1) Map of the geothermal gradient in the upper part of the earth's crust of the USSR (schematic version), compiled in 1965, revised in 1967; 2) Map of temperature distribution on the surface of the crystalline and folded basement of the USSR (schematic version), compiled in 1963, revised in 1967. For translated legends of these maps see detailed discussion of the book Teplovoy rezhim nedr SSSR (Heat regime of the earth's interior in the USSR area) appearing in Part I of this report.

ON THE QUESTION OF THE ENERGY OF ACTIVE VULCANISM

Kovalev, G. N. IN: Vulkanizm i glubiny Zemli (Volcanism and the depths of the earth). Papers presented at the Third All-Union Volcanological Conference, 28-31 May 1969. Izd-vo Nauka, Moscow, 1971, 41-46.

Gives data on the total heat capacity (10^3 kcal/sec) and specific capacity of the hydrothermal systems (kcal/km^2-sec) at the following sites of USSR thermoanomalies: Semyachik volcano (Kamchatka) - 75 and 870 - 750, respectively, over an area of 80-100 km^2; Uzon, Geyzernaya (Kamchatka) - 6475 and 870, respectively, over an area 160 km^2; Mendeleyev volcano (Kurile Islands) - 5.4-4.8 and 900-800, respectively, over an area of 6 km^2; and Golovnina volcano (Kurile Islands) - 12.8-9.5 and 1070-790, respectively, over an area of 12 km^2.

NATURE OF THE HEAT ANOMALIES IN THE VOLGA-URAL OIL AND GAS BASIN

Yerofeyev, V. F. Sovetskaya geologiya, no. 5, 1969, 81-90.

Five temperature-anomaly zones are identified in the Volga-Ural oil and gas basin. Positive temperature anomalies are associated with deep faults and do not reach the high-intensity level, the maximum temperatures recorded being 66°C at the 2000 m level at Sidorovskaya.

FUMAROLE ACTIVITY OF THE BEZYMYANNYY VOLCANO (NORTH KAMCHATKA) IN THE 1966-1967 PERIOD

Serafimova, Ye. K. Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 47, 1971, 23-28.

Tabulates in detail the chemical composition and temperatures of the volcanic gases collected from the fumaroles of the older cones and a new cone developing on the sides of the volcano. The temperatures of the fumaroles located near the base of the new cone dropped from 170° in 1965 to 80° in 1967.

RADON IN THE SPONTANEOUS GASES OF THE BANNYYE, KOSHELEVSKIYE AND KIREUNSKIYE (KAMCHATKA) HOT SPRINGS

Chirkov, A. M. Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 47, 1971, 69-71.

Results of chemical analyses made of the spontaneous gases contained in samples taken from the hot springs of three areas are tabulated, along with their temperatures (°C), as follows: 1) the Malo- and Bol'she-Bannyye Springs - 40° to 100°; 2) the Koshelevskiye field - 35° to 99°; 3) the Kireunskiye springs - 48° to 98°.

ON THE REGIME OF THE PAUZHETKA BOILING SPRINGS AND GEYSERS

Sugrobova, N. G. Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 47, 1971, 72-75.

Previous studies carried out on the behavior of the boiling springs and geysers in the Pauzhetka field, had indicated that,. for the most part, their activity was relatively constant with the exception of Geyser II. Fluctuations in the activity of these geysers are investigated as a function of atmospheric pressure and position relative to the low-water level of the nearby Pauzhetka River acting as a possible source of cool ground water supply.

PART III. BIBLIOGRAPHIES

Introduction

This section of the report contains bibliographic information relating to geothermal power sources and is structured to reflect: 1) late 1971 - early 1972 information which will be exploited in forthcoming geothermy reports; and 2) citations (some retrospective to about 1964) to references which contain background, supplemental or marginal-interest information on geothermal problems. These sources could be exploited in detail in future reports in response to reader interest. In general, Section 2 is intended to supplement and update existing bibliographies. Unless specific interest is expressed, no further exploitation of information in this Section is anticipated at present. Other current and some retrospective materials, particularly relating to the power generation systems, are being investigated and will be described in subsequent reports.

Section 1. Current Selections in Geothermy

Denisik, V. A., and I. M. Zaytsev. Some results of geophysical studies at the Paratunka geothermal fields. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Geologiya i geofizika, no. 7, 1971, 92-100.

Lajos, Belteky. New possibilities for the study and use of thermal waters in the Bekes region. Hidrologiai kozlony, v. 51, no. 5, 1971, 224-231.

Tskhvirashvili, D. G., and O. Sh. Vardigoreli. Corrosion of metals in geothermal water. Vodosnabzheniye i sanitarnaya tekhnika, no. 12, 1971, 8-10.

Zoltan, Nagy. Data on the Kerekes hot spring in the city of Debrecen. Hidrologiai kozlony, no. 1-2, 1972, 74-76.

Section 2. Bibliography of Geothermy

Aver'yev, V. V., and Ye. A. Vakin. Thermal fields of the Bol'shoy Semyachik volcanic massif. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulletin' vulkanologicheskikh stantsiy, no. 42, 1966, 3-16.

Belousov, V. I. Geological structure of the hydrothermal systems of Kamchatka. Builetin volcanologique, v. 30, 1967, 63-73.

Bogomolov, Yu. G. Geotemperature regime. IN: International Association of Scientific Hydrology. Bulletin, v. 12, no. 4, 1967, 86-91.

Borisov, O. C., and I. B. Nikitina. States of fumaroles of the Sheveluch and Bezymyanniy volcanoes in 1960. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 33, 1962, 3-19.

Borzasekov, V. F. Geothermal conditions and thermal waters of central and eastern Turkmenia. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 207-216.

Brezgunov, V. S., V. M. Dunichev, A. V. Zotov, I. I. Riznich, V. N. Soyfer, and R. I. Tkachenko. Genesis of the thermal waters of the Mendeleyev volcano (Kunashir Island). IN: Akademiya nauk SSSR. Doklady, v. 179, no. 1, 1968, 179-182

Cheremenskiy, G. A. Study of hydrogeological section of western Siberian lowlands, from geothermograms. International geological review, v. 9 no. 11, 1967, 1458-1465. (TRANSLATED FROM: Sovetskaya geologiya, no. 12, 1966, 71-80.

Chikhradze, Sh. G. Results of geothermal investigations in the Kolkhid plain. IN: Soveshchaniye po geotermicheskim isslodovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 141-146.

Dumanskiy, S. G., and D. I. Kul'chitskiy. Geothermal characteristics of oil and gas deposits of the Carpathian foreland depression and application of geothermal methods of investigation for exploration of deep-seated structures. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 75-84.

Dunichev, V. M., and I. I. Riznich. Steam hydrotherms of Goryachiy Plyazh (new data on the results of borehole work in 1966). IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 44, 1968, 60-64.

Dzhamalova, A. S. Glubinnyy teplovoy potok na territorii Dagestana (Deep-seated heat flow in Dagestan). Moskva, Izd-vo Nauka, 1969, 128 p.

Fotiadi, E. E., and U. I. Moiseyenko. The heat field of the West Siberian platform. IN: Academy of Sciences USSR. Doklady. Earth Sciences Section, v. 189, nos. 1-6, 1970, 50-52. (TRANSLATED FROM: AN SSSR. Doklady, v. 189, no. 2, 1969, 385-388.

Gavlina, G. B. Geothermal characteristics of intramontane basins of southern Siberia and the Far Eastern territory. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Reseacch in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 252-265.

Geodekyan, A. A., and F. A. Makarenko. Extrapolation of temperatures at depth in the southern Caspian tectonic depression. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 187-192.

Gordiyenko, V. V. Nature of the geothermal anomalies of the Crimean peninsula. Geofizicheskiy sbornik, no. 18, 1966, 64-70.

Gusev, N. A., Ye. Ya. Karizhenskiy, and B. V. Shilin. Infrared aerial mapping for studying regions with present geothermal activity. Sovetskaya geologiya, no. 1, 1972, 114-119.

Kashkay, M. A. Role of relationships of transverse and linear structures in the geothermal regime of the Caucasus region. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 207-216.

Khalismatov, I. Effect of the folded basement on the thermal state of the sediments in the northwestern part of the Bukhara-Khivinsk gas- and oil -bearing region. Uzbekskiy geologicheskiy zhurnal, no. 1, 1972, 106-110.

Khasanov, A. S., and T. B. Grebenshchikova. Some geothermal indexes of the Bukhara-Karshi artesian basin. Uzbekskiy geologicheskiy zhurnal, no. 5, 1966, 59-63.

Kheladze, I. Ye. Investigation of heat conditions at depth in Georgia. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 146-147.

Kortsenshteyn, V. N. Geothermal regime of the Caucasus foreland, the Kara-Bogaz-Gol area, and western Uzbekistan with reference to problems of utilization of thermal waters. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 192-200.

Kortsenshteyn, V. N. The Zhuravka geothermal anomaly. IN: Academy of Sciences USSR. Doklady. Earth Sciences Section, v. 181, 1968, 22-24. (TRANSLATED FROM: AN SSSR. Doklady, v. 181, no. 1, 1968, 175-177.)

Kotov, V. N., and V. N. Matviyenko. Geothermal conditions and thermal water resources of the Azov-Kuban oil and gas basin. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 94-102.

Kovalev, G. N. Heat output of hydrothermal systems and active volcanoes. IN: Academy of Sciences USSR. Doklady. Earth Sciences Section, v. 186, nos. 1-6, 1970, 15-16. (TRANSLATED FROM: AN SSSR. Doklady, v. 186, no. 4, 1969, 814-816.)

Kul'chitskiy, D. I., and V. G. Osadchiy. Heat field and distribution of oil and gas pools in the West Ukrainian oil and gas region. IN: Academy of Sciences USSR. Doklady. Earth Sciences Section, v. 179, 1968, 25-27. (TRANSLATED FROM: AN SSSR. Doklady, v. 179, no. 1, 1968, 162-165.

Lipatskova, Ye. N. Thermal waters of the Volga-Don region. IN: Akademiya nauk SSSR. Doklady, v. 172, no. 6, 1967, 1412-1415.

Lysak, S. V. Nekotoryye dannyye o termal'nykh vodakh i geotermike Pribaykal'ya (Data on thermal waters and geothermal characteristics of the Baikal region). Moskva, 1968, ? p. (AT HEAD OF TITLE: AN SSSR. Sibirskoye otdeleniye. Institut zemnoy kory.)

Makarenko, F. A., and B. F. Mavritskiy. Thermal and superheated waters of the USSR. Sovetskaya geologiya, no. 8, 1963, 78-94.

Makarova, O. A. Temperature regime of the Bibi-Eybat oil field. IVUZ. Neft' i gaz, no. 10, 1967, 17-20.

Matviyenko, V. N. Results of geothermal investigations in the Kuban'. Geologiya nefti i gaza, no. 8, 1968, 35-38.

Mavritskiy, B. F. Classification of ground water, based on temperature index. IN: Vsesoyuznyy nauchno-issledovatel'skiy institut gidrogeologii i inzhenernoy geologii. Trudy, Novaya seriya, no. 9, 1964, 198-205.

Mavritskiy, B. F., and O. P. Bulygina. Thermal waters of the central regions of the West Siberian basin and their practical significance. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 227-232.

Merzhanov, A. G., A. S. Shteynberg, and G. S. Shteynberg. Theory of the geyser process. Akademiya nauk SSSR. Doklady, v. 194, no. 2, 1970, 318-321.

Miroshnikov, M. M., Ye. Ya. Karizhenskiy, B. V. Shilin, and N. A. Gusev. Thermal imaging in studying natural resources from the air. Optiko-mekhanicheskaya promyshlennost', no. 3, 1970, 3-9.

Miroshnikov, M. V., and K. I. Vorob'yeva. Geothermal characteristics of Mesozoic-Cenozoic deposits and prospects for utilizing the thermal waters of the Stavropol' region. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 103-108.

Nazarov, S. N. Geothermal features of the Fergana oil and gas basin. Geologiya nefti i gaza, no. 8, 1968, 38-42.

Ovnatanov, S. T., and G. P. Tamrazyan. Relation of geothermal conditions to structure, with examples from the Apsheron peninsula and adjacent littoral marine zones. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 159-163.

Ovnatanov, S. T., and G. P. Tamrazyan. Thermal studies in subsurface structural investigations, Apsheron Peninsula, Azerbaydzhan, USSR. IN: American Association of Petroleum Geologists. Bulletin, v. 54, no. 9, 1970, 1677-1685.

Plyushch, A. M., and N. K. Kadyrov. Heat flow in the Siazanskiy monocline. IN: Akademiya nauk Azerbaydzhanskoy SSR. Izvestiya. Seriya nauk o Zemle, no. 2, 1971, 68-69.

Polevoy, S. L., and I. P. Kovshov. Calculation of commercial reserves of thermal water in a pressurized system, with examples from the Caucasian foreland. IVUZ. Geologiya i razvedka, no. 10, 1968, 79-85.

Polyak, B. G. An energy appraisal of volcanic and hydrothermal phenomena (on the example of Kamchatka). Bulletin volcanologique, v. 30, 1967, 129-138.

Rozin, A. A. Thermal waters of the southern part of the West Siberian basin and their significance for the national economy. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 232-238.

Serafimova, Ye. K. Specific features of the chemical composition of the fumarole gases of Mutnovskiy volcano. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 42, 1966, 56-65.

Shteyn, M. A. Thermal waters of Sakhalin and their utilization. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 274-280.

Sidorov, S. S. Activization of the Ebeko volcano in 1963 - 1964, and the evolution of its hydrothermal activity in the period prior to activization. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 40, 1966, 61-69.

Sidorov, S. S. Hydrothermal activity of the Golovnin caldera (Kunashir Island). IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 42, 1966, 22-29.

Skripko, K. A., Ye. M. Fil'kova, and G. G. Khramova. State of the Ebeko volcano in the summer of 1965. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 42, 1966, 42-55.

Stremyakov, A. Ya. Hydrogeothermal conditions of the Chukchi peninsula and possible uses of its hydrothermal resources. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 280-283.

Sukharev, G. M., and S. P. Vlasova. A solution to certain problems connected with the replenishment of subsurface thermal water resources in the Terek-Sunzha oil and gas region. IN: Academy of Sciences USSR. Doklady. Earth Sciences Section, v. 168, nos. 1-6, 1966, 10-12.

Vakin, Ye. A. Aag (Aak) mineral hot springs on Kamchatka. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 41, 1966, 35-40.

Vakin, Ye. A. The spatial and genetic relation of the thermal waters of southeastern Kamchatka to active volcanoes. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 284-288.

Vlasova, S. P., and Yu. K. Taranukha. Geothermal characteristics of the Mesozoic-Cenozoic section and paleogeothermal conditions of the Caucasus foreland. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 115-120.

Voronova, L. G., and S. S. Sidorov. Hydrothermal activity of the Karpinskiy Khrebet volcanoes (Paramushir Island). IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 41, 1966, 41-49.

Yermakov, V. A. Hot springs in the western part of the Kumroch Ridge. IN: Akademiya nauk SSSR. Sibirskoye otdeleniye. Institut vulkanologii. Byulleten' vulkanologicheskikh stantsiy, no. 42, 1966, 30-32.

Zhevago, V. S. Geothermal investigations in Kazakhstan and utilization of thermal waters. IN: Soveshchaniye po geotermicheskim issledovaniyam v SSSR. 2nd, Moskva, 1964. Trudy (Transactions of the Second Conference on Geothermal Research in the USSR. Moscow, 1964). /Moskva/, 1967, v. 2, 219-225.

Zhevago, V. S. Patterns of heat distribution in the upper part of the earth's crust in Kazakhstan. IN: Akademiya nauk Kazakhskoy SSR. Institut gidrogeologii i gidrofiziki. Trudy, no. 1, 1968, 158-173.

Zotov, A. V., I. P. Laputina, and A. V. Chichagov. Arsenopyrite from the hot springs on Kunashir Island (Kurile Islands). Geologiya rudnykh mestorozhdeniy, no. 1, 1972, 125-131.